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AGROMISA

Agrodok 5 - Fruit growing in the tropics

Fruit growing in the tropics

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Agrodok 5

Fruit growing in the tropics

Ed Verheij

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Foreword

The previous editions of this Agrodok, published in 1992 and 1999, gave a general introduction into fruit growing in the tropics and described 8 major crops. Working on this revision, the general introduction quickly filled the entire Agrodok! And if the major fruit crops are to be dealt with anew, each crop will no doubt require an Agrodok of its own. In fact it may be better to publish regional crop manuals, rather than trying to cram information for various parts of the tropics into a single booklet.

The aim of this revised text is to foster your interest in and understanding of fruit growing. Traditional knowledge has been combined with insights gained through research work. No recipes are given for growing specific fruit crops. The contents are directed at home gardeners, growers who depend for (part of) their income on the sale of fruit, extension workers and others who support gardeners and growers.

Acknowledgement
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Wageningen, August 2006
Ed Verheij

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1 Introduction

1.1 No flowers, no fruit

So you are interested in growing fruit! Perhaps you already grow fruit in a home garden or in an orchard, or you intend to do so. This Agrodok is written to make you feel at home amidst the different fruits crops you see around you. More than 60 fruits are mentioned in the text. The Index at the end lists the botanical names and the pages on which you can find more information about these fruits. There is also an Appendix with particulars about the flowers (in connection with pollination), the fruit, the seed and the common methods of propagation.

No flowers, no fruits! Scanty flowering is the main reason for disappointing crops in the tropics. Hence the flowering habit of a fruit crop is extremely important. Flowering habit is linked with tree habit, as explained in Chapter 3. A few very common fruit crops – pineapple, banana, papaya, (also palms) – have the growth habit of a single large shoot. These fruits as a rule flower and fruit well if they grow well. So they respond to the common measures to stimulate growth – watering, manuring, crop protection – that every farmer knows about. But the large majority of the fruit crops branch freely issuing hundreds or thousands of shoots. Each of these trees branches in its own typical way. These freely branching trees get the most attention in this Agrodok, because they are the problem crops that often flower poorly.

The main reason for scanty flowering is simple: the tree ‘forgets’ to form floral buds because it is too busy making new shoots. In fact most branched fruit crops require a period of stress – in the form of a cold or dry season – to put a stop to shoot growth in favour of laying down floral buds. And if the natural stress is inadequate – as is the case in large parts of the tropics for many fruit crops in most years, you will need to check shoot growth yourself. In such tree crops, therefore, measures to limit shoot growth and measures to stimulate growth should be alternated according to the seasons. Thus the grower

of these fruits needs special skills and has to apply them at the right time. The aim is to achieve a better *BALANCE* between vegetative growth and reproductive growth (the course of events from the initiation of floral buds to ripening of the fruit). This is the subject of Chapter 6.

Pruning, discussed in Chapter 5, is one of the skills employed in branching trees. But in the tropics the results of pruning are all too often negative. The main reason is that pruning leads to compensatory regrowth, which sets back the formation of floral buds. Thus pruning is important mainly when trees flower and fruit abundantly, so that shoot growth needs to be stimulated rather than flowering,

Without flowers no fruit. But also: without pollination no fruit set! There are exceptions to this rule, but flowers generally need to be pollinated, preferably by cross-pollination, to set fruit. Fruit crops differ greatly in the types of flowers they bear and in the way pollination and fruit set is effected. This important subject is dealt with in Chapter 7.

1.2 Importance of trees and fruits

Big trees and small trees

Trees are the natural vegetation in large parts of the tropics, in particular, in humid regions. The importance of trees stems partly from their large size and perennial character. Trees shape the landscape and frame buildings; they cast their shade over man and beast. They protect the soil against the hot sun, heavy rain and strong winds, especially during seasons when there are no annual crops in the fields. The roots explore deep soil layers, recycling water and nutrients that cannot be reached by the roots of field crops. In these ways, trees ameliorate their immediate environment.

There is increasing evidence that trees protect and exploit the environment more effectively than annuals. Evergreen trees have the advantage over seasonal crop plants in that the canopy of leaves is present throughout the year. Agrodok 16: Agroforestry, explains the role

of trees in more detail, both in the environment and in the farming system.

As a fruit grower you harvest fruit, not leaves and wood. Unfortunately, the so-called ‘harvest index’ – that is the share of fruit in the total amount of organic matter produced – is often quite low, especially for most freely branching fruit trees. The tomatoes, eggplants, cucurbits, etc. of the vegetable grower may not exploit the environment nearly as well as the tree fruits, but they yield many more tons of fruit per ha than most trees. Perhaps you should grow vegetables...

People think it natural that trees grow to a large size, but in fact trees grow big because poor flowering and fruiting leave enough energy for ever more shoots to grow. As a fruit grower your aim should be to produce fruit with a minimum of wood! If you could make a tree bear a full crop – in relation to its size – each year, starting within a few years from planting, it would never grow big. Imagine a mature mango tree the size of a coffee bush: think of the ease of pruning, crop protection, selective harvesting... For the fruit grower *SMALL IS BEAUTIFUL*. This is the conclusion of Chapter 2, in which the different cropping systems for fruit are compared.

Cloning is the first step towards control over tree size, as explained in Chapter 4: Propagation. In Chapter 9, Harvesting, it is argued that large tree size and top quality fruit do not go together: harvesting each fruit when it is at its best is impossible and avoiding blemishes is difficult.

Who eats fruit and why?

In Africa fruit is often considered as ‘food for the birds’ (Swahili:”chakula cha ndege”) and it is left to children to compete with the birds; a man – it is said – should drink beer. In Central and South America, people are usually more fruitminded. Asians generally have a great appreciation of fruits.

The regard for fruit appears to be related to the propagation methods. Until recently fruit trees in Africa were commonly raised from seed; hence there were no named varieties or cultivars (banana being an important exception). Asia, on the other hand, is the area of origin of several important cloning methods, enabling growers to propagate superior varieties. Appreciation of the distinct taste of each variety developed through the ages. Home gardens flourish, people are familiar with home preservation and cooking methods, and aware of the health benefits traditionally attributed to each fruit. But for all that most people in Asia must make do with far less fruit than they would like to eat.

1.3 Reasons NOT to grow fruit

This booklet is meant to put across new ideas to gardeners, growers and extension workers. The intention, of course, is to encourage you to grow fruit. Nevertheless it is only fair to briefly list reasons not to grow fruit as well, even though you have probably thought of these reasons yourself.

No doubt you took into account that it takes years before you can harvest the first crop. And when the trees come into bearing they may fail to flower, or to set fruit, or that the fruit may drop prematurely. But, supposing the trees are doing fine: have you considered the risk of fire scorching your trees? And what about pilferage, birds, bats and rats eating the fruit, not to say anything about losses due to other pests and diseases?

The fruit grower faces a lot of uncertainty in producing a crop and, if there is a good crop to be picked, there is still the uncertainty of the market. There is truth in the saying that producing a fruit crop is the lesser half of the problem, post-harvest handling and marketing representing the larger half...

Hopefully you have given proper thought to all these risks, problems and possible setbacks, because this Agrodok cannot do it for you! For

one thing, the contents are limited to fruit production. Some aspects, such as out-of-season production, are related to marketing, but marketing as such is not dealt with. Local markets and customary arrangements with middlemen vary so much and the market situation changes so rapidly when the production of a new fruit increases, that marketing advice should be based on local conditions.

In Chapter 8 the principles of controlling pests and diseases are discussed with some examples. Finally, if you have considered all the above objections and still are about to plant fruit trees, you will find recommendations in Chapter 10: Layout and establishment of the orchard.

2 Cropping systems for fruit

Fruit is produced in almost every farming system. Some fruits are collected in the natural vegetation ('in the wild'). In shifting cultivation systems, fruit trees are often planted along with the field crops after a plot has been cleared. During the first year or two of the next fallow period the resurging natural vegetation is slashed to enable the fruit trees to survive and bear fruit. In this way Amazon Indians enrich the fallow vegetation with a range of indigenous fruit crops, such as canistel, Amazon tree grape, pejibaye and other palms.

2.1 The home garden

From the more permanent plot around the hut of the shifting cultivator to the home garden of the settled farmer is only one step. The original meaning of the word 'garden' (as well as 'hortus' from which 'horticulture' is derived) is 'fence' or 'enclosure'. Horticultural crops are grown within the enclosure, field crops outside it. The enclosure offers protection so that the family, not passing goats and school children, can gather the harvest. There are a great many garden crops. They are grown on a small scale – partly because they are perishable – and together they fill the garden throughout the year, making protection all the more necessary.

Protection is easiest if the garden surrounds the house: the home garden. This also facilitates crop care. Many husbandry techniques, explained in textbooks but rarely seen in the field, such as watering by hand, composting, mulching, pruning, trellising and simple crop protection measures, are common in the home garden. Protection and care ensure that the home garden supplies small quantities of fruits, vegetables and herbs to supplement the diet, but also medicinal products, some fodder for the animals, and amenities such as wooden posts and bamboos.

2.2 Orchards and plantations

Near the growing towns some home gardens developed into market gardens and further specialisation led to new professions: vegetable grower, fruit grower, nurseryman, etc., all producing primarily for the market.

However, of the many different fruit crops in home gardens only a few are found in orchards producing for the market. The reason is both simple and shocking: fruit growers cannot grow these crops profitably, because they produce too little and/or too erratically, and it takes too many years bvefore they bear fruit! Why plant an orchard of durians if you have to wait up to 10 years for the trees to produce a worthwhile crop? And look at the mango trees in your area: people notice a single tree full of fruit, but tend to overlook 10 others that hardly bear any fruit. In fact the mango, one of the most important fruit crops, bears so erratically that it is difficult to estimate what a "normal" yield is. On the other hand, pineapple and banana are so productive that investors are prepared to finance large-scale plantations of these fruits. This is shown in figure 1 where home gardening is compared with the more commercial cropping systems.

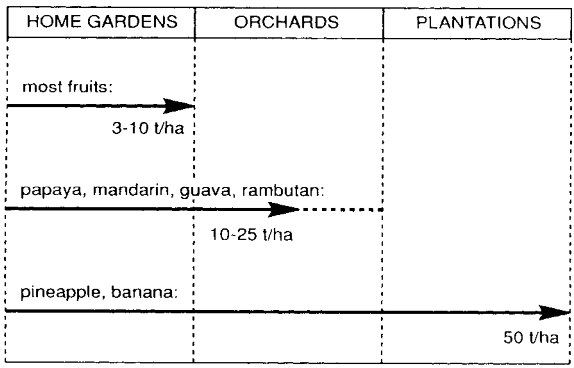


Figure 1: Cropping system, crops and yield levels. All cultivated fruit crops are grown in home gardens, but only those that bear good crops are found in more commercial cropping systems.

Some fruits are only found growing in the wild; all cultivated fruits are grown in home gardens, but only a few have made it as orchard or plantation crops. Looking more closely at figure 1 it is clear that the crops suited to production in orchards or plantations are not only high-yielding; they also need only a short period from planting to full production, and they remain small. Pineapple and banana, the 2 plantation crops, show these properties in the extreme.

2.3 Small is beautiful

High yield and early production are associated with small tree size. For the fruit grower *SMALL IS BEAUTIFUL*! This point is emphasised throughout this booklet, because traditionally people want their trees to grow *BIG*. After all the distinctive feature of a tree is its size. Big, or rather tall, is indeed beautiful for the forester. However, *as a fruit grower you are after fruit, not wood.*

Apple growing in the Netherlands provides a striking example of the move towards smaller fruit trees. From 1930 to 1970 the average number of trees per ha increased from 100 to 2,500 (the spacing decreased from 10m x 10m to 3.20m x 1.25m). In these 40 years the mean yield in the country increased from 8 to 32 ton per ha!

If trees remain small you need a lot more trees per ha, but this drawback is offset by rapid attainment of full production. Moreover, small trees are so much easier to manage: pruning, crop protection, harvesting, etc. can all be done much more efficiently. Early bearing, easy-to-manage, small trees should bring down the cost of fruit production, so that the grower can make a profit even at much lower market prices, enabling many more people to buy fruit.

Whereas control over tree size is essential for the commercial fruit grower, it is also beneficial for home gardeners. Just imagine your one large mango tree being replaced by 3 or 5 more fruitful small mango trees of different varieties! (But these trees may be too small to sit in

their shade...) Ways to control tree size will be discussed in later chapters, with emphasis on the first step, clonal propagation (Chapter 4).

2.4 Summary

Fruits play a role in almost all farming systems. Some fruits are collected in the wild, a variety of fruit crops are used to enrich the vegetation of fallow fields in shifting cultivation, and the widest variety of fruit crops is found in home gardens. Only a minority of tropical fruits are suited to commercial production in orchards. The largest commercial enterprises, such as corporate plantations, are virtually limited to pineapple and banana. Commercial fruits crop heavily and regularly; usually they come into bearing quickly and the trees remain small.

Progress in fruit growing relies strongly on methods to limit tree size, because small trees tend to be more productive than large ones and are much easier to manage, leading to lower costs of production. The principal method to achieve this is by vegetative propagation.

3 Form and function

3.1 Single-stemmed and branched fruit crops

There are a few fruit crops that come to the fore wherever the growing conditions permit their cultivation: papaya, coconut, pineapple and banana. The growth habit of all these plants resembles a single, giant shoot. That is why we call them single-stemmed plants (although, strictly speaking, this is not correct – see Box). This shoot grows continuously, the growing point at the shoot tip forming leaves and inflorescences in orderly succession.

Papaya and coconut form flowers in the axil of every leaf, pineapple and banana flower at the shoot tip after sufficient leaves have been produced to sustain fruit growth.

The form of these single-stemmed crops implies that if they grow faster they will also flower and fruit sooner. Moreover, leaves and fruit grow to a larger size when growing conditions are favourable. For the grower these are relatively simple crops, because they respond well to crop care (watering, manuring, crop protection). If only you make sure that the plants grow well they will produce high and predictable yields. Because the growing point is always active, fruit can be harvested at any time of the year. So it is not surprising that these crops are grown wherever possible; they are important to rich and poor.

Different forms of branching

Banana and pineapple form suckers, which are in fact branches. However, suckers do not much affect form and functioning of the mother shoot, so here we just consider both crops (and suckering palms such as date palm and pejibaye) as single-stemmed plants. You may have seen papaya plants that through some mishap have formed a few branches. Because each of these branches resembles the unbranched papaya in form and functioning, we still include such plants in the single-stemmed category.

Branching of the true branched fruit crops is of a different order. They branch to adapt their form to the available space (branches grow towards the light). Vines are the champions in this respect; they have no fixed form at all. The form of a vine depends on the support it finds in searching for light.

Continuous and intermittent growth

The single-stemmed fruit crops are only a small, but extremely important, minority. By far most fruit crops are freely branching trees. The shoots of most of these branched species do not grow continuously but intermittently. Shoots extend during a flush, rapidly unfolding a number of leaves. Before long the shoot stops growing, no longer issuing young leaves and matures into an apparently resting twig.

Single-stemmed crop plants can grow continuously because as soon as they have a full set of leaves the leaf area remains the same, each new leaf replacing a withering leaf. Nearly all water and nutrients needed by a tree are taken up by *young* roots. That is why roots cannot stop growing; otherwise there soon would be no young roots anymore. The fairly constant leaf area of single-stemmed plants can be supplied with water and nutrients if the roots grow at a steady pace.

The roots of branched trees would have to grow ever faster if the number of shoots and leaves increases unchecked. This is impossible and may explain why most branched trees grow intermittently rather than continuously. During a flush the number of leaves increases so fast that the root system cannot keep up. After the flush, however, growth of the roots continues and leaf fall gradually reduces the leaf area. So after a period of (many) months, the tree is again able to support a flush. As a result the shoot: root ratio in branched trees is not steady, but fluctuates. Under favourable growing conditions there may be a rapid succession of flushes, so that branching becomes quite complex within a few years, as shown in figure 2.

Which buds will flower?

For the fruit grower the most striking feature of branched fruit crops is that flowering and fruiting have no well-defined place in the growth habit, in contrast to the single-stemmed crops.

A papaya or coconut that grows reasonably well flowers in every leaf axil once the juvenile period is over, but it is impossible to say which of the hundreds or thousands of twigs on a mango tree are going to

flower and fruit. The tree may flower profusely in one year and hardly at all in another. Consequently bearing of branched trees is unpredictable and much lower on average than in single-stemmed fruit crops.

Since growth comes first, stimulating growth is unlikely to improve flowering and fruiting. For instance: watering a mango tree during the dry season to avoid stress will lead to more flushing at the expense of flowering. Figure 2 shows the rapid increase in branching of a mango tree growing in ever-wet conditions; the tree did not flower at all.

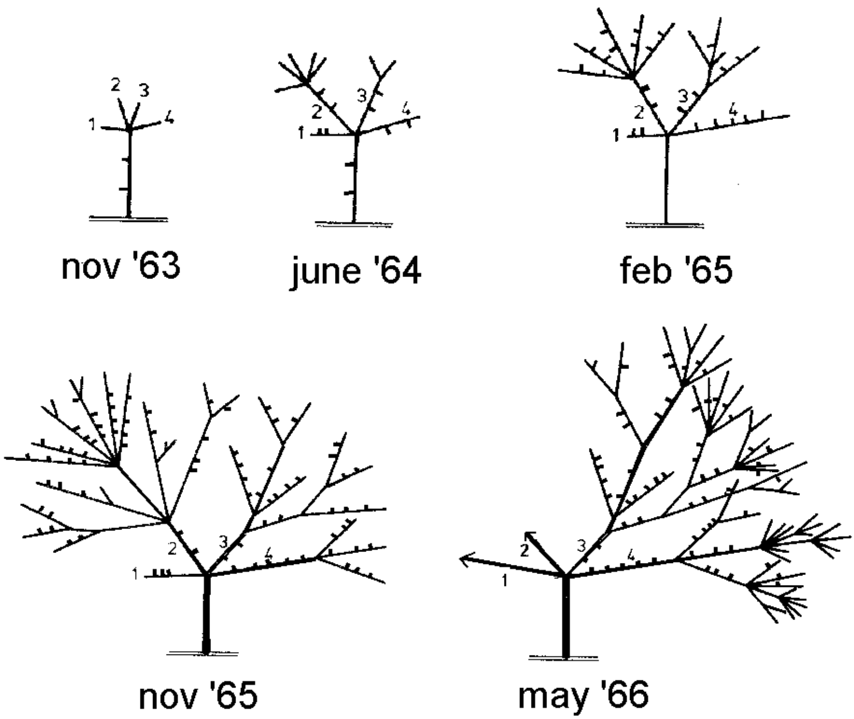


Figure 2: Branching of a mango tree in Madagascar over 2½ years from planting. All flushing shoots were measured and recorded, but in May 1966 only on two branches. Dots show the end of the previous flush.

Shoots and buds

In this book we use the terms shoot and twig for the young branches. As soon as the youngest leaves on the shoot have matured, the shoot becomes a twig. A twig bears only mature leaves (the oldest leaves may already have fallen). A twig only grows by becoming a thicker branch, but some buds on a twig may break to produce flowers or new shoots during a later flush.

In fruit growing 'flower bud' is often used as opposed to 'leaf bud', to indicate the bud that in due course will break into an inflorescence, bearing one or more flowers. Here we use the term 'floral bud', because In common usage 'flower bud' stands for a flower just before it opens.

Stress and seasonal yield

While the grower of single-stemmed fruit crops does his best to make sure that his crops do not suffer stress, for intermittently growing branched fruit trees a period of stress is in fact welcome – or necessary. A period of unfavourable weather, like a cold or dry season, stops shoot growth and gives the twigs time to initiate floral buds. Low temperature is more effective than drought, as can be shown by comparing fruit crops such as citrus, mango and avocado, which grow in the subtropics as well as in the tropics (see Box).

Citrus, mango and avocado in the tropics and subtropics

For all three crops, a rule of thumb is that in the tropics the trees grow twice as fast and yield only half as much as in the subtropics. In the tropics the dry season often does not check shoot growth effectively, resulting in large trees and insufficient twig rest to ensure good flowering and fruiting. In the subtropics, winter does stop shoot growth; moreover it stimulates formation of floral buds, resulting in small, profusely flowering trees. But in the subtropics inclement springtime weather often leads to poor fruit set. And if fruit sets well this may lead to overbearing and shortage of shoots that flower next year, resulting in biennial bearing.

Thus, although the crops are the same, the problems faced by the grower are quite different; in several respect they are quite the opposite. Think twice before you adopt recommendations based on experience in the subtropics!

Seasonal stress imposed by climate and soil conditions results in simultaneous flowering of all trees of a crop (or cultivar). Consequently the fruit of most branched trees has a short market supply season,

whereas the fruits of single-stemmed plants are available throughout the year.

The striking differences between single-stemmed and branched fruit crops in fruiting and in the required crop care are summarised in Table 1. In the following Sections we shall discuss each of these groups in more detail, also considering differences within each group.

Table 1: Comparison of single-stemmed and branched fruit crops

Single stemmed crops: e.g. banana, papaya, coconut	**Branched crops:** e.g. mandarin, guava, mango
Growth continuous	Growth intermittent
Shoot : root stable	Shoot : root fluctuates
Yield - high	Yield - low
- predictable	- erratic
- year-round	- seasonal
Improved growing conditions raise fruiting more than growth.	Improved growing conditions generally stimulate shoot growth at the expense of flowering/fruiting.
Advice: stimulate growth, minimise stress	Advice: use seasonal stress to BALANCE shoot growth with flowering/fruiting

3.2 A closer look at single-stemmed fruit crops

The four single-stemmed fruit crops mentioned before, fall into two groups: papaya and coconut produce flowers in the axil of every leaf; banana and pineapple flower at the shoot tip. Growth and flowering/fruiting are closely linked in all these plants: if they are growing well the yield will be high. Under adverse conditions however, important differences between the two groups come to light.

Flowering in the leaf axils

Papaya and coconut have to keep up a steady rate of growth to be able to produce flowers and fruits in every leaf axil. If growing conditions deteriorate, for instance during a cold or dry season, growth goes on as best it can at the expense of flowering and fruiting. In other words: under stressful conditions flowering and fruiting are sacrificed for the

sake of the tree. Therefore these crops require favourable growing conditions throughout the year; they are confined to the tropics.

If you look at the trunk of a papaya tree you see the scars of the leaves that have fallen. The small leaves formed during an adverse season leave small scars close together, quite distinct from the large, well-spaced scars of leaves formed during a favourable growing season. If the papaya is a few years old you can read its life history, its periods of happiness and stress, from the leaf scars on the stem, as shown in figure 3. The form reflects the way in which the tree functions.

Thus the first task of the papaya grower is to reduce stress to a minimum, for instance by watering during the dry season, by planting the trees on a ridge if the soil is poorly drained, or by providing shelter on a wind-swept plain.

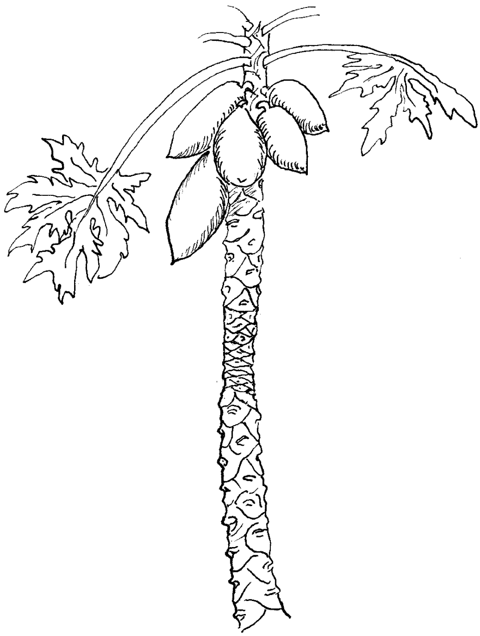


Figure 3: Leaf scars on a papaya trunk

In an orchard spacing of the plants is important. If papayas or coconuts are planted close together the leaves cannot spread out freely and are forced in a more upright position. The resulting narrow leaf axils hinder the development of flowers and fruits. Lack of space, like a period of stress, sets back flowering and fruiting much more than vegetative growth. Coconut palms are often spaced so far apart that they can be intercropped, because nut production drops sharply if the palms are

planted too close together. Hence these species are designed for unrestricted growth, both with respect to time and space.

Flowering at the shoot tip

If a banana plant is stressed by drought or cold weather, leaf production slows down and, if the stress persists, the new leaves gradually become smaller. Unlike the papaya, this does not directly affect fruit yield. The main effect of a period of slower growth is that appearance of the bunch is delayed: you have to wait longer to harvest the fruit. Similarly, if you cut a banana leaf now and then to use as an umbrella or to wrap up your food, you postpone the harvest rather than reducing it. The same applies to the pineapple, a drought-resistant crop that can virtually suspend growth in dry conditions.

The leaves of closely spaced bananas or pineapples also assume a more upright position. The crowding results in a more slender plant and smaller fruit, but that loss can be made good by the larger number of plants per ha. The small pineapples preferred in international trade are produced by reducing the planting distance.

Terminal flowering banana and pineapple adapt much better to adverse conditions than papaya or coconut. The harvest is delayed but not necessarily reduced by a period of stress. This is why both crops are also popular in the subtropics; in the tropics they grow up to elevations of around 1600 m. Flowering at the shoot tip enables these crops to cope fairly well with stress and crowding.

Other single-stemmed crops

The palms are by far the largest group of single-stemmed perennial crop plants. Oil palm, pejibaye, arecanut and date palm are examples of important crops with the same growth habit as coconut. There are also palms, for instance sago palm, which flower at the shoot tip like banana; sisal is another example of this growth habit.

Table 2 summarises the main characteristics of the two groups of continuously growing fruit crops.

Table 2: Characteristics of the two groups of single-stemmed fruits

Flowering habit	**in leaf axils**: growth and flowering combined	**at the shoot tip:** flowering after completion of growth
Examples	papaya, coconut	pineapple, banana
Response to stress	growth continues at the expense of fruiting	growth slows down and fruiting is delayed
Adaptation to:		
- climate	thrive only under minimal stress	can adapt to drought or cold
- close spacing	plants grow taller, yield per ha declines	plants grow taller, smaller fruit size, but more fruits per ha
Conclusion	growth habit inflexible; designed for undisturbed growth in time and space	growth habit flexible; fruiting does not suffer much from seasonal stress or close spacing

3.3 Form and function of branched fruit trees

Intermittent and continuous growth

The large group of branched fruit trees is very diverse. We have already seen that branching is commonly associated with intermittent shoot growth, scanty flowering and seasonal fruiting. That branching and intermittent growth are closely related is shown by the changes in the growth habit during the course of the life of branched trees, especially if grown from seed.

As a rule the seedling grows continuously, but intermittent growth is seen as soon as the first side shoots are formed. With increasing branching the interval between flushes tends to become longer and more twigs generally remain at rest during a flush. From a distance the tree may seem to be in full flush, but if you look closely you will see that many twigs are at rest. (These resting twigs may be the ones that are going to flower!) Trees propagated vegetatively tend to grow intermittently from the start, but as branching becomes more complex, you will notice similar changes in flushing pattern as in trees grown from seed.

Some woody plants are able to grow continuously and flower in leaf axils on the growing shoot, like the single-stemmed papaya. The clearest examples are vines, such as passionfruits and grape. In their search for light their shoots grow on and on until – with increasing branching – growth of the shoots slows down. Breadfruit and coffee are examples of tree crops showing continuous growth in combination with flowering in the leaf axils. Jackfruit and durian also have shoots that tend to grow continuously, but these trees flower on the main branches and trunk ('cauliflory'). Whereas intermittently growing shoots (in flushes), stop growing even under ideal conditions, continuous shoot growth is brought to a stop by adverse conditions, such as drought or a load of growing fruits, as in coffee and passionfruit.

In this Section we focus on intermittently growing trees, because the majority of the fruit crops, including nearly all important ones, belong to this group. However, continuously growing fruit crops are occasionally mentioned too.

Shoot growth patterns

Growth of the flushing shoot may follow a 'go – stop' rhythm, stopping abruptly by abortion of the growing point, as in cocoa and often in citrus shoots. More often the growing point forms a resting terminal bud, covered in bud scales, as in mango. In the 'resting' bud the growing point continues to lay down leaf initials, which will unfold when the bud breaks during the next flush. Flushing can also follow a 'fast – slow' rhythm, growth slowing down to a snail's pace after the rapid unfolding of leaves at the start of the flush, until it picks up again in the next flush (rambutan, nutmeg). In this case the 'resting' bud is usually naked, not covered by bud scales.

Shoot growth is called 'determinate' if during a flush only leaves unfold that had already been laid down in the bud. If the shoot tip continues to form new leaves, the flush is prolonged and shoot growth is said to be 'indeterminate'. Several fruit crops bear both determinate shoots (short shoots, called spurs in pomegranate, apple, pear, plum) and indeterminate shoots (long shoots, called whips in plum and cus-

tard apples). Indeterminate shoots may be seen as a step towards continuously growing shoots. You can observe the various flushing patterns on your own trees.

Fitting flowering/fruiting in with shoot growth

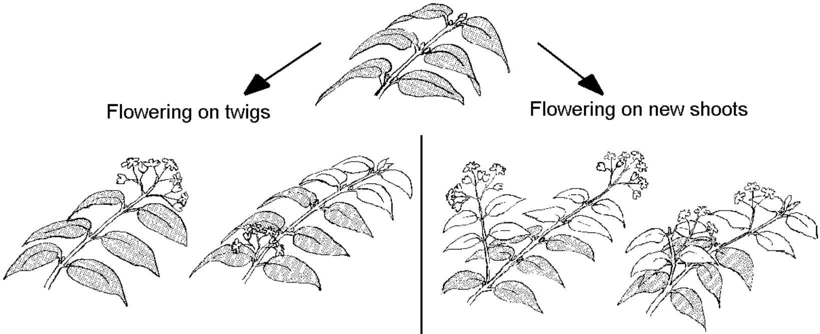
Branched trees have a much more flexible habit of growth than single-stemmed plants. Unfortunately for the fruit grower, however, this flexibility is gained at the expense of flowering and fruiting. The natural function of fruiting is to provide the seeds needed to produce the next generation. So it is not surprising that branched trees have made adaptations to ensure seed production as best they can in spite of liberal shoot growth. Two strategies are common: shoot growth and reproductive growth take place *at different times* or *in different locations.*

Separation in time

Intermittently growing fruit crops use the time between flushes for floral development: apart from a few exceptions, they lay down floral buds on the resting twig. Hence, these crops combine flowering/fruiting with free branching by separating the two: shoot growth and floral development take place at different times.

Floral buds may be formed in leaf axils or at the tip of the resting twig. As these floral buds break, they may either produce only an inflorescence, or a flushing shoot with inflorescence(s). Figure 4 depicts the four possibilities with examples. Note that quite a few fruit crops flower both in the leaf axils and at the tip, or directly on the twig as well as on the new shoots.

As shown in figure 4, guava flowers in leaf axils of the flushing shoot. However, these flowers were already initiated before the bud on the resting twig flushed. Inside the bud that is about to break you can see under the microscope the leaf initials which will expand during the flush, but also the first signs of floral development in axils of these tiny leaf initials. In other words: the events that lead to flowering on new shoots commonly start on the resting twig.



at the tip	in leaf axils	at the tip	in leaf axils
mango	citrus	citrus	guava
cashew	custard apples	custard apples	
avocado	jujube	jujube	
rambutan	sapodilla	persimmons	
longan	canistel	santol	
loquat	Malay apple *		
mangosteen	mamey sapote*		
casimiroa	casimiroa		
tamarind	tamarind	tamarind	tamarind
apple **	apple **		
pear **	pear **		

*Figure 4: Flowering on twigs and shoots, at the tip and in leaf axils, with examples. Note that many fruit crops form flowers in more than one position. *) Flowering only on leafless parts **) Breaking buds form a rosette of leaves and a cluster of flowers.*

Flowering in separate locations

Custard apples, pomegranate, apple, pear and plum all lay down floral buds on the resting twig; they also have both long (indeterminate) and short (determinate) shoots. The growth of the short shoots terminates early, allowing these ‘spurs’ more time to initiate flowers. Although flowering occurs on long twigs too, flowering and fruit set are much better on the spurs. Hence these crops combine separation of shoot growth and floral development in time with preferential flowering in special locations.

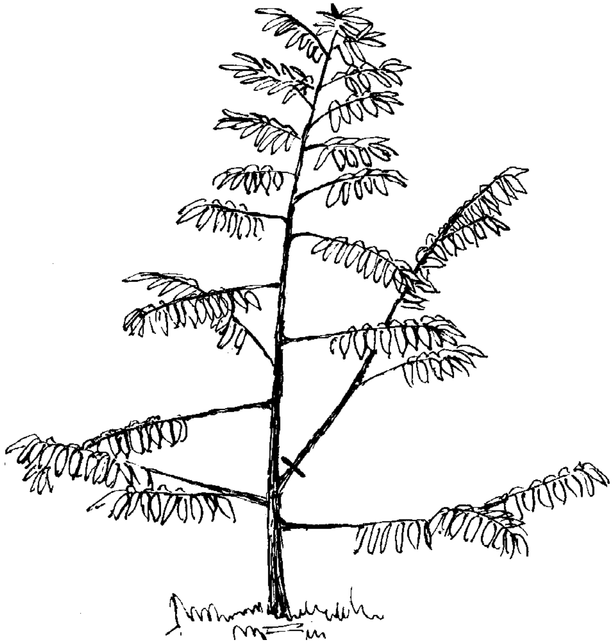


Figure 5: Young durian tree with horizontal 'feathers' and one vigorous upright branch. By cutting that branch you keep the tree small and foster the growth of more fruitful branches.

Coffee is an example of flowering on special, continuously growing shoots. Coffee has quite distinct shoot types: one or more upright shoots ('orthotropic' shoots), each with numerous horizontally growing side shoots ('plagiotropic' shoots). Only the plagiotropic shoots bear flowers. Several fruit crops have a tendency towards plagiotropy, be it not as extreme as in coffee. Durian, for instance, has mainly horizontal (plagiotropic) branches and usually one or several sturdy upright (orthotropic) branches. The distinction between the horizontal 'feathers' and upright vigorous branches is quite clear in young trees, as shown in figure 5. Unlike coffee, both types of branches bear fruit, but the orthotropic branches mainly contribute to tree size and the plagiotropic branches mainly add to the crop.

Durian has more or less distinct shoot types, but the most striking feature is that its flowers are formed on the underside of the branches close to the tree trunk. Flowering on the tree trunk and main branches, called cauliflory, is a very effective way of allocating shoot growth and floral development to different locations. It sets shoot growth free: durian and jackfruit shoots grow more or less continuously, while the shoots of cocoa grow in frequent flushes.

The above examples of durian, custard apples, etc. show that combined strategies to better separate flower formation and shoot growth are common. Nevertheless, poor flowering remains the main factor limiting yield of branched fruit crops. This applies in particular to crops that lay down floral buds on resting twigs. These crops form a large and important group. Although the behaviour of these crops is still poorly understood, an approach towards improved flowering is outlined in the following paragraphs.

Floral buds on resting twigs

In spite of the fragmentary information it appears that adequate flowering depends largely on two conditions:

- Synchronous flushing
- No flushing shoots before and during the formation of floral buds.

Synchronisation of flowering

Synchronous flushing means that the tree goes through distinct phases for shoot growth and floral development. If a large proportion of the twigs produces new shoots simultaneously, these shoots mature at the same time, becoming resting twigs that in due course should produce a synchronous flowering flush. Indications are that flowering is more profuse if not just individual twigs, but the entire tree gets into ‘floral mode’. Such a concentrated bloom also favours pollination and fruit set. The resulting clear-cut annual crop cycle greatly facilitates tree management, as it establishes a proper time for fertilising, pruning, crop protection treatments, harvesting, etc. (see Chapter 6).

Synchronisation results from stress imposed by the environment. Tree species differ greatly in the severity of stress required to ensure synchronous shoot growth and synchronous flowering. A degree of synchronisation is the rule, even in the humid tropics, where a brief dry spell or a cooling shower after a few hot days are the main upheavals in the weather. Some rubber clones even shed their leaves in response to a change of weather that most people do not notice. Spondias species (ambarella, mombin) stand leafless following a brief ‘dry’ spell. Loss of leaves enables the roots to trigger a synchronous flush, be it a flowering flush or a flush of shoots. Other fruit crops at home in the humid tropics, such as rambutan and mangosteen, often bear fruit twice a year, but not sporadically throughout the year. (However, depending on the timing of the stress, bloom – and consequently the harvest period(s) – may shift considerably from year to year.)

Fruit crops that thrive in a monsoon climate require much more stress to force synchronous flushing. If grown in a humid environment they grow even more vigorously, continuous haphazard flushing suppressing the formation of floral buds. This is what happened to the mango tree in figure 2 and explains the frequent growth of new shoots and the absence of flowers. The only fruit crops that seem to bear just as well when growing in a non-synchronous way are sapodilla, soursop and nutmeg.

Although a degree of synchronisation is the rule, synchronisation is often far from perfect. It is not unusual to see a tree in full flush and a neighbour that is at rest, as in figure 6, or a single branch in flush while the others are at rest, or scattered flushing of shoots throughout the wet season. The non-synchronous flushing shown in figure 6 is likely to be repeated at harvest time, as is the case in figure 7!

Figure 6: Rambutan in the dry season, the tree in front flushing, the one behind at rest

Figure 7: Bearing rambutan tree (right) and flushing tree without fruit (left)

Prevent shoot growth when floral buds are to be formed

Because synchronisation of flushing is far from perfect in the tropics, there is a risk of shoot growth shortly before and during the period that floral buds are laid down. Shoot growth while the tree is switching to floral mode should be prevented. It is generally assumed that floral development proceeds without interruption, leading from the first signs of floral initiation to bloom in 3 – 8 weeks, depending on the species. There are some – perhaps even many – exceptions to this rule (see Box). But the few indications we have suggest that twigs should rest for 2 – 4 months before bloom. If floral development does take 3 – 8 weeks, this leaves a month or two of twig rest before the start of floral development.

If you observe flushing and bloom of fruit trees around you for a few years, you can find out for yourself whether or not late shoot growth leads to poor flowering.

From bud to flower: some exceptions to the rule

For several reasons floral development may take much longer than 3 – 8 weeks. Development may simply proceed slowly; in clove it takes more than 6 months. Also, twigs often rest much longer than necessary to lay down floral buds. As long as few leaves are shed the roots may not trigger bud break, even though floral buds are ready. Another important reason is bud dormancy, which is the inability of buds to break, although growing conditions are favourable. Floral buds of coffee go dormant as soon as they are formed. Drought gradually breaks the dormancy, and finally a shower triggers bloom of all floral buds that are no longer dormant.

Fruit crops from the temperate zone (apple, pear, plum, peach, grape) have buds that go dormant in the course of the growing season. Winter chilling breaks the dormancy and bloom follows when the temperature rises in spring. When these crops are grown in the tropics bud break tends to be delayed and inadequate. Dormancy-breaking chemicals can be used to improve bud break; some of these chemicals are also used to put an end to prolonged twig rest (see Chapter 6).

Stress imposed by the environment

In the subtropics seasonal stress affects fruit crops much more clearly than in the tropics. A cold season enforces a strict annual crop cycle, also on fruit crops that are grown in the tropics as well, such as citrus, avocado, mango, longan, lychee, loquat, jujube, pomegranate and casimiroa. During the winter there is no shoot growth. This leads to a general flush dominated by flowers when the temperature rises in spring (the cold season apparently also stimulates the formation of floral buds). When fruit set is good, the burden of growing fruits suppresses flushing, so that a post-harvest flush is needed to provide the twigs that will carry the floral buds for next year’s crop. Thus the cold season and a good crop together leave little room for excessive shoot growth. This is a good thing: in principle shoot growth is needed only to renew the fruiting wood; more shoot growth increases tree size at the expense of fruit production.

In the tropics environmental stress comes mainly in the form of drought. It is impossible to consider the entire range from humid to arid conditions here. But just consider a typical monsoon climate with wet and dry seasons of near-equal duration. In this situation shoot growth occurs mainly during the wet season, starting with a synchronous flush following the onset of the rains. Synchronisation may get lost with further flushing of shoots in the course of the wet season. The dry season soon brings shoot growth to an end. Presumably floral buds are laid down on the resting twigs around this time, for most branched fruit crops flower during the dry season. Depending on the time needed from bloom to harvest, the fruit ripens towards the end of the dry season or early in the wet season, the period with the greatest assortment of fruit in the market.

Now compare the crop cycles in the subtropics and tropics.

- In the subtropics release from stress results in springtime flowering; fruit grows during the growing season (summer); if the crop is good, shoot growth is restricted to a post-harvest flush in autumn.
- In the tropics not only floral initiation, but also flowering and most fruit growth take place during the stress period (drought). The flush early in the wet season coincides more or less with the post-harvest flush, leaving most of the growing season for – largely unwanted and increasingly non-synchronous – shoot growth.

Thus it is clear that in a monsoon climate it is not easy to satisfy both conditions for good flowering: synchronous flushing and no late shoot growth. In a drier climate irrigation can be used to control the annual crop cycle; in a more humid climate the crop cycle tends to be even less well defined. What you as a grower can do to strengthen synchronisation and to prevent late flushing is discussed in Chapter 6.

Environmental stress does not only come in the form of drought. In most tropical regions the (early) dry season also happens to be the cool season. The drop in temperature may be just a few degrees centigrade and as it coincides with drought it is difficult to say how effective it is. Thailand's reputation as a fruit growing nation rests on the cool air of the Asian landmass flowing far south, adding to the dry season stress. As a result many fruit crops flower in 'spring' as far down as Bangkok.

Low light levels due to overcast skies appear to contribute much to environmental stress. In Gabon overcast weather during the dry season, caused by the Gulf Stream in the nearby Atlantic, leads to profuse flowering of mango and butter fruit. Depletion of nitrogen in the soil after the rains may also curb shoot growth. All four stress factors, drought, cool weather, overcast skies and low nitrogen levels, are at play in the successful production of the subtropical lychee and macadamia near the equator in the East African highlands, in a climate with two dry and two wet seasons.

As shown in the above examples, success with branched fruit crops often depends on a favourable combination of stress factors rather than growth factors! Stress imposed by climate and soil conditions (particularly the availability of moisture) varies so much that specific fruit growing recipes are needed per country or region.

As a grower you are only concerned with the local environment, but you face another complication: large variations in stress from year to year. The dry season is not as reliable as the cold season and interruption by rain may be very detrimental, the more so because effects carry over into the next year. An extreme example is given in the Box. Although such a complete failure of the dry season is exceptional, treatments to enhance natural stress in order to prevent late flushing are no luxury (see Chapter 6).

Variability of rainfall during the dry season

Rainfall during the dry season in an orchard near Franceville, Gabon

Year(s)	June	July	August
1979-86, average	37	25	59 mm
1984	160	119	294 mm

The normal dry season did not occur in 1984 and oranges and mandarins did not flower. The crop failure in 1984 is bad enough, but it also disturbed the annual growth rhythm: in the absence of fruit all the trees' energy went into vigorous and prolonged shoot growth. Consequently few twigs were sufficiently mature to flower in 1985.

So too much rain in the dry season not only led to crop failure in 1984, but also to a light crop in 1985. Moreover hard pruning was needed to restrict tree size. If an annual crop fails you start with a clean slate in the next year. When a tree crop fails (and also when the crop is heavy) the negative effects carry over into next year's crop!

3.4 Summary

The different growth habits discussed in this chapter, together with the way in which they flower, are summarized in the Box below. No flowers, no fruits; the predictable flowering of single-stemmed fruit crops is in sharp contrast with the erratic flowering of the branched fruit crops. Shoot growth and formation of floral buds in separate locations or at different times are adaptations to give flowering a more secure place in the growth habit of branched fruit crops. Separation in time is effective in the subtropics (the winter does it), but in the tropics strong efforts are needed to synchronise flushing and to prevent flushing when formation of floral buds is due.

Grouping of fruit crops according to growth habit and position of floral buds

1. SINGLE-STEMMED SPECIES
    - 1.1 Continuous growth and floral buds in the leaf axils
        - papaya, coconut
    - 1.2 Continuous growth, ending in floral bud at the shoot tip
        - banana,pineapple
2. BRANCHED SPECIES
    - 2.1 Continuous shoot growth and floral buds in leaf axils
        - breadfruit, passionfruit
    - 2.2 Growing shoots and floral buds separated:
        - 2.2.1 in different **locations**:
            - floral buds on trunk and branches: cauliflory
                - jackfruit, durian, cocoa
            - floral buds (mainly) on specialised twigs
                - coffee, durian; atemoya, pear; grape.
        - 2.2.2 flushing shoots separated from floral buds **in time**:
            - non-synchronous flushing and floral buds found year-round
                - sapodilla, soursop, nutmeg
            - poorly defined annual crop cycle, triggered by mild stress
                - rambutan, mangosteen
            - well-defined annual crop cycle, imposed by fierce stress
                - mango, orange, kapok

4 Propagation

Most tropical fruit trees are still propagated from seed, especially in home gardens. In fruit growing, vegetative propagation opens the way for a breakthrough in productivity and efficiency so that production for the market becomes more attractive.

4.1 Seedlings or clonal plants?

Sexual reproduction leads to *SEEDLING VARIATION*: although all seedlings resemble the mother tree in some respects, no two seedlings are the same. Differences between the seedlings will of course become even larger if they are grown under different conditions.

In vegetative propagation a part of the mother tree other than the seed, (e.g. a cutting) becomes a new plant. The genetic make-up of this new plant is exactly the same as that of the mother tree. Consequently all cuttings from one mother tree are identical; they have the same characteristics. The mother tree, together with the cuttings, is called a *CLONE*. Differences between plants of a clone can only be caused by different growing conditions.

A clone is a cultivar (short for cultivated variety) and can be named. This is a great advantage in marketing. Fruit quality is variable and in many cases hard to judge when purchased. So it is a great leap forward if a ‘Fuerte’ avocado can be sold, instead of just an avocado.

Seedlings are juvenile; they are unable to flower until they become mature. A seedling inevitably grows into a sizable tree before it can bear fruit. This commonly takes 3 to 10 years, depending on the species. If cuttings are taken from a mature tree, the new plant, however small, is mature and may flower even in the nursery.

This is the principal difference between a seedling and a cloned tree. Early bearing siphons energy into fruit growth that would otherwise

have been used for shoot growth and production of wood. So clonal trees remain smaller and can be planted close together. More trees per ha means further increases in the early crops! Taking the cuttings from a high-yielding mother tree also contributes to increased production. Moreover, as discussed in Chapter 2, small trees are much easier to manage, which greatly reduces the cost of production per kg fruit.

Conclusion:
Clonal propagation is the key to intensification and higher yield: fewer unproductive years, more trees per ha, higher maximum yield per ha, much higher mean yield over the orchard's lifespan, more efficient management and lower cost of production.

Clonal propagation also has disadvantages:

- Very few diseases are transmitted through seed, but a special effort is needed to ensure the health of mother trees to be cloned, because diseases and pests that infest the tree may be transmitted to cuttings, layers or bud- and graftwood.
- Seedlings, with their strong taproot and juvenile phase, have a very robust start in life. Cloned trees have a much weaker root system and are expected to produce fruit rather than wood. Consequently an orchard of clonal trees requires intensive husbandry, in keeping with the intensity of cropping.
- Production of seedlings is cheap compared to clonal propagation, especially in case of layering, budding or grafting. And because the cloned trees remain smaller, more trees are needed to plant a given area.
- Finally, since all plants in a clone have the same genetic make-up, a new disease or disorder that breaks down the genetic defences is likely to affect the entire clone. To minimise this risk it is wise to plant a few different cultivars together (this also facilitates cross-pollination).

Notwithstanding these disadvantages, progress in fruit growing has been achieved largely through the use of clonal planting material. Only a few fruit crops are still grown from seed: papaya, passionfruit, soursop, cashew.

The juvenile phase of these crops is very short: less than a year for papaya and passionfruit and only 3 - 4 years for soursop and cashew.

4.2 Outline of cloning methods

Table 3 shows the common methods of vegetative propagation. Starting with natural forms of cloning, the methods generally become more complex from top to bottom. It takes far less time to set 100 stem cuttings than to prepare 100 air layers. Preparing 100 approach grafts requires even more time and skill.

The table is split into two sections. The top half presents methods in which plants are propagated on their own roots. In the bottom half a rootstock provides the root system. Presumably these methods, which require more skill, originated in Asia several thousand years ago. Modern refinements are largely based on the many applications of plastic materials.

Table 3: Cloning methods, with examples, starting with simple ones at the top.

Propagation on own roots		
Natural	Asexual seedlings	apomixis – mangosteen polyembryony – mango, citrus
	Adapted shoots	suckers – banana, pineapple layers – raspberry runners – strawberry
Man-made	Rooting after separation (cuttings)	Root cuttings – breadfruit, plum Stem cuttings – grape
	Rooting on mother plant	Layering – guave, blackberry Air layering – longan, lime
Propagation on rootstock		
Budding		T-budding – citrus, apple Chip-budding – citrus Patch-budding – avocado, rubber
Grafting	On rootstock in the nursery	Tip grafting – young, tender stock Side grafting – mature, woody stock
	On mother tree in the field	Inarching – durian, lansat, jackfruit Approach grafting – mango

Agrodok 19: Propagating and planting trees, is a practical manual for simple propagation techniques. In addition to propagating from seed it also describes most methods in the upper part of Table 3: propagation through cuttings and different forms of layering. There are also suitable manuals describing budding and grafting methods (see Further reading and Agrospecial 1: A nurseryman and his trees.). The more unusual cloning methods in Table 3 are briefly explained below.

Asexual seedlings

Apomixis is reproduction by seed without sexual fusion. The seed of the mangosteen is not a true seed. When it germinates the first root appears at one end of the 'seed', the young shoot at the other end. This situation is similar to a cutting striking root; it shows that the seed corresponds to a stem piece. As shown in figure 8 a second root system soon emerges at the base of the shoot.

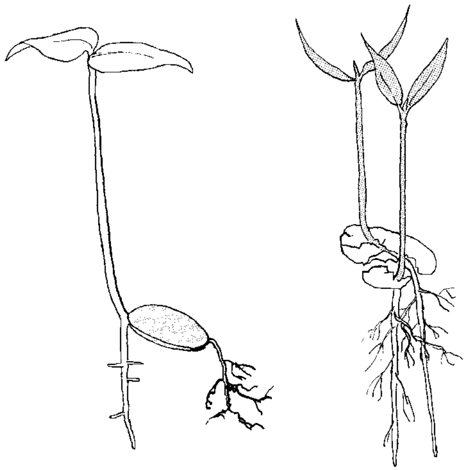


Figure 8: Asexual seedlings. Left mangosteen, right mango

A normal seed contains a single embryo, the result of sexual reproduction; it grows into a seedling. Polyembryony implies the presence of more than one embryo. The extra embryos are formed in maternal seed tissue and therefore are clonal offspring of the mother tree, so that several seedlings grow out of a single seed (figure 8, right). In most cases the original (sexual) embryo does not develop, because it is suppressed by the other embryo(s). That is why many mango and citrus cultivars can be propagated true to kind from seed.

Grafting on a mother tree in the field

In approach grafting both rootstock and scion are intact plants. Their stems are spliced together to unite them. Scaffolding is set up under the mother tree to hold pots with rootstocks in position close to the scion branches. This is the most elaborate method, the more so since the rootstocks require regular watering.

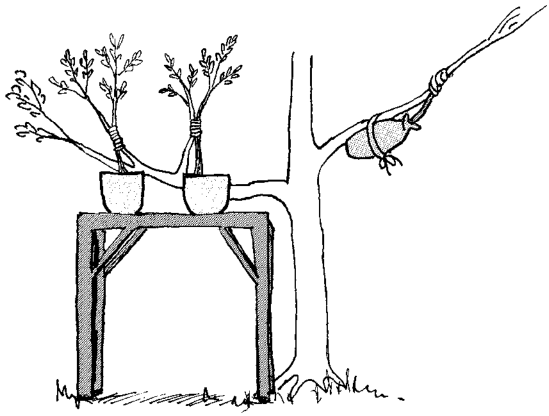


Figure 9: Left: approach grafting with intact rootstock. Right: in-arching, the rootstock is cut back and inserted in the mother tree

Inarching may be considered as a form of approach grafting. First a rootstock is raised; grafting consists of cutting back its stem and inserting the cut end into the scion tree. In this way a poorly anchored tree (for instance following root damage by rodents) can be rescued by planting a few rootstocks around it and inarching these in the trunk. A form of inarching used in South East Asia to propagate trees in large numbers is called suckle grafting. The rootstock is bagged and tied to a sturdy twig of the mother tree. The cut end of the rootstock is inserted in a cleft made in the twig (figure 9, right). Because the soil ball is completely enclosed in the bag, the rootstock needs no watering; in fact it gets no attention till graft union has been achieved!

4.3 Concluding remarks

Most fruit crops can be cloned in different ways. Budding and grafting are only used where cuttings or layers do not root, or where the rootstock offers important advantages such as: restricted tree size (apple), salt tolerance (avocado), better fruit quality (citrus) or tolerance to diseases (avocado, citrus). Broadly speaking, simple methods require more attention to environmental conditions (e.g. shade, humidity) in the nursery. The more sophisticated methods demand more time and skill. Therefore the simple methods are more suited to mass propagation, since they require little labour per plant and the cost of creating a suitable environment is shared by a large number of plants.

Commercial fruit growers depend on nurseries specialising in only a few fruit crops and producing the leading cultivars in large numbers at competitive prices. Such a specialised nursery should also be able to guarantee the health of the stock. A nursery with small numbers of all sorts of fruit trees huddled together under a shade tree waiting for a buyer cannot meet these requirements.

5 Training: pruning and bending

5.1 Definition; the limited role of pruning in tropical fruits

Pruning is the removal of unwanted growth in order to stimulate desired growth: something is removed to obtain a certain response. It follows that you cannot judge pruning solely by the looks of the tree immediately after pruning or by the amount of cut wood lying under the tree. The quality of pruning can only be judged after the plant has had time (say: a growing season) to respond.

With experience you can predict the response to some extent. However, growing conditions modify the tree's response to pruning. If tree vigour is moderate and the tree is going to bear a good crop the response is more predictable. Weak or excessively vigorous growth and failure to bear make the response to pruning more erratic. Experiments (for instance in citrus) usually show yield reductions following pruning, and no clear-cut advantages.

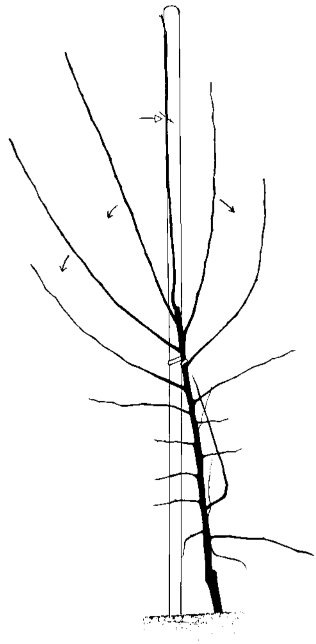


Figure 10: Bending down vigorous shoots that compete with the leading shoot.

A shoot or branch can be placed in the desired position by bending. This is an attractive alternative to pruning, particularly for young trees that still have to fill the allotted space. The trend to replace pruning to some extent by bending has led to a much more rapid increase in cropping volume, for instance in tea ('pegging down') and apple (figure 10). Training is a combination of bending and pruning.

Vines have to be trained on a supporting trellis. The cheapest way is to use live posts for a vertical trellis (e.g. for pitahaya), a T-shape trellis (e.g. for passionfruit) or an overhead pergola (for grape). The overhead structure can consist of bamboo crossbars that support the wires. Agrodok 19: Agroforestry, lists tree species that can be trained as live posts.

People often think that pruning is needed for trees that grow too vigorously. This may be true for young trees, but bending vigorous shoots or imposing stress (as explained in Chapter 6) is usually a better solution. However, bearing trees in fact need to be pruned when shoot growth has been weakened by heavy fruit loads, to the extent that (the quality of) the next crop is endangered. By setting back flowering/fruiting, pruning restores tree vigour and enables the tree to produce another high-quality crop.

First heavy crops, then pruning
A useful rule of thumb is: pruning encourages renewed growth at the expense of flowering/fruiting. Thus there is not much scope for pruning until the yield levels of tropical fruit are greatly improved.

How much new shoot growth is generated by pruning and how flowering and fruiting are affected depends mainly on which portion of the shoot or branch is cut.

5.2 Cutting increasingly large portions of a shoot/branch

According to where the shoot, twig or branch is cut, pruning can be classified as follows (figure 11):

- Tipping or pinching: removal of the shoot tip;
- Cutting back: removal of a substantial portion of the shoot;
- Stubbing: cutting near the point of attachment of the shoot, leaving only a stub;
- Cutting out or thinning: removing the entire shoot by a cut at the point of attachment.

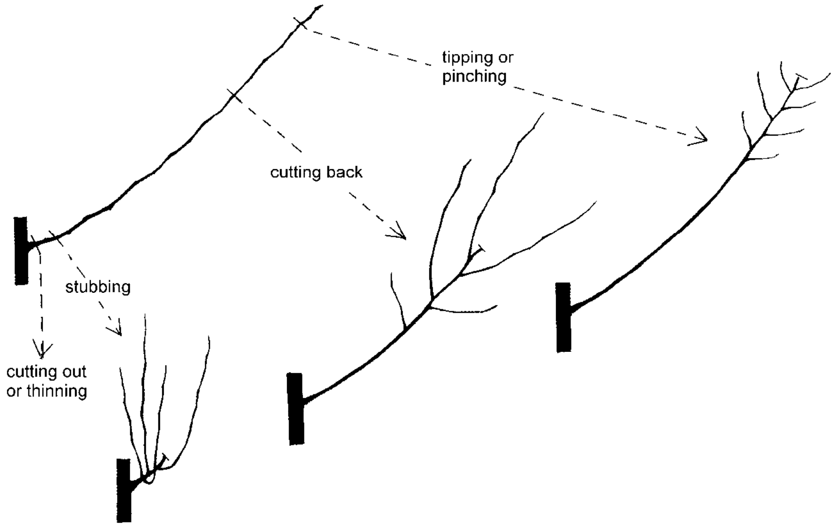


Figure 11: Growth response to cutting increasing portions of a twig

Tipping

Tipping, usually called pinching when done with the fingernails, sounds like the most delicate of pruning methods, but the response is dramatic. Many buds in the leaf axils below the cut sprout and grow into (fairly weak) shoots. The result is a sharp increase in branching, as you can see from the reaction of tea to harvesting and that of hedges to trimming. An important side effect is that flowering is suppressed: plucked tea bushes and regularly trimmed hedges do not flower at all. Hormones produced in the shoot tip inhibit sprouting of the buds in the leaf axils; that is why the response to removal of the shoot tip is so strong.

When the vigorous shoots of a young grape are trained along the wire to form the permanent arms, repeated tipping ensures that side shoots emerge in virtually every leaf axil of these shoots. This is necessary because the side shoots later become the spurs that will bear the fruiting canes. Excellent growing conditions (generous manuring, timely watering) are of course needed to sustain the growth of the main arms and to support the growth of all these side shoots.

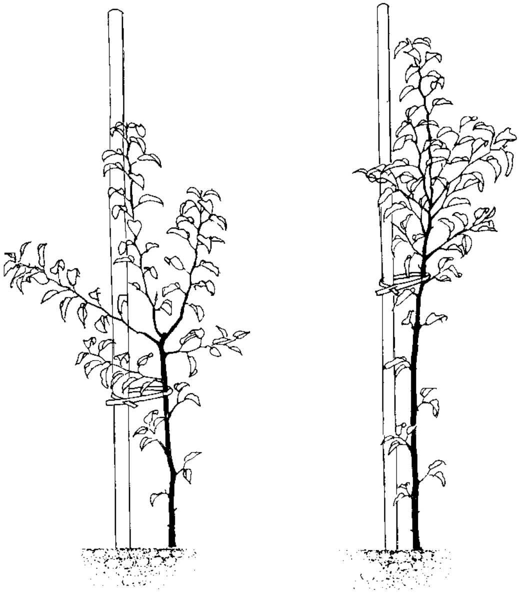


Figure 12: Shoot growth following cutting back (left), in comparison with shoot growth of an unpruned tree (right)

Cutting back

When more wood is removed than just the shoot tip the treatment is called cutting back. The response changes as a larger portion of the shoot is cut: fewer side shoots grow out and they are more vigorous, especially the uppermost ones. The latter grow at a small angle with the branch; further down the angle gets wider as the shoots get weaker (see figure 11). Vigorous growth of the shoot tip in young unbranched trees means a strong flow of hormones inhibiting side shoots. Cutting back, either in the nursery or after planting, is the way to ensure branching of maiden trees at the desired height (see figure 12); note that the leading shoot in figure 10 has also been cut back. Cutting back is also practiced on so-called whips, very vigorous unbranched shoots, in young annona and plum trees. Again the objective is to force the whips to form short side shoots that are more likely to bear fruit, as shown in figure 13.

Stubbing

Stubbing is making a drastic cut, leaving only a stub of the shoot or limb. The general response is the growth of several shoots of near-equal vigour. The reason is that on the stub only underdeveloped, dormant buds are present. It takes a bit longer for these buds to sprout and there is no dominance of the uppermost bud. Stubbing is the way to prune ornamental shrubs, such as hibiscus, since growth of a number of equivalent shoots is exactly what is needed. Sometimes trees are drastically rejuvenated through stubbing (also called stumping), e.g. coffee, citrus, peach. In that case, thinning is needed to leave only the required number of shoots for the new framework.

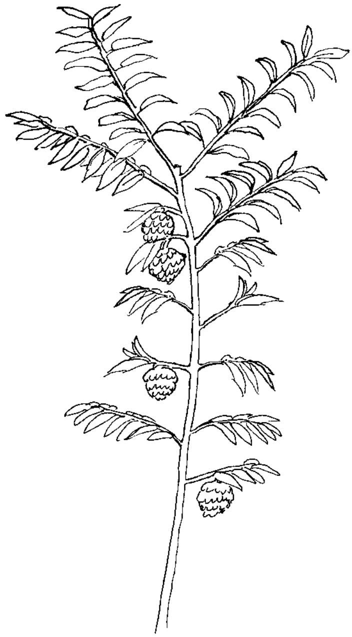


Figure 13: Fruiting side shoots on a sugarapple whip that was cut back

Cutting out

Cutting out or thinning is the removal of complete shoots or branches. This is the most drastic cut, yet the response of the tree is rather mild. Often there is no renewed growth at all near the cut, the response is dispersed over the rest of the tree. Because of its obvious direct effect and the moderate reaction of the tree, *THINNING IS THE PRINCIPAL PRUNING METHOD.* You can see immediately what you have done and need not worry too much about the after-effects.

Hand the shears to an untrained person and he will start cutting back, shortening shoots and branches. He neither wants to cut too much nor too little, but in fact he is maltreating the tree. Cutting back leads to compensatory growth and stimulates branching; whereas tipping tends

to suppress flowering completely, cutting back greatly reduces flowering. Apart from the examples of maiden trees and whips given above, there is little scope for cutting back in fruit growing. Bad experiences with pruning of tropical fruit trees are based in part on this cut, while the alternative, cutting out, is often overlooked.

Cutting out is the way to relieve overcrowding in the tree crown. Telltale signs are inferior fruit quality, poor flowering and fruit set, or early leaf fall in the interior of the canopy. (If the trees are too close together, some should be uprooted because pruning cannot solve this problem.) Thinning is also practiced in the case of excessive flowering (coffee: cut out some plagiotropic shoots) or excessive fruit set (citrus: cut out some twigs with large numbers of fruitlets) to maintain the vitality of the tree.

Removal of ageing, sagging branches to the point where a younger shoot emerges (usually where the branch bends downwards) is a common form of thinning in apple, pear and plum. It is a way of rejuvenating the fruiting wood to prevent a decline in fruit quality. Examples of cutting out in young trees include the removal of upright branches in durians which will dominate the feathery horizontal branches (See figure 5) and, in the year after planting, the brushing off of side shoots emerging too low on the trunk to become permanent limbs (see Chapter 10).

5.3 Summary

Training of trees and vines consists of pruning and bending. Bending reduces the need for pruning, thus enabling young trees to expand more quickly. Pruning plays a modest role in the tropics because it stimulates compensatory growth of shoots at the expense of fruiting; this is seldom necessary because most crops are shy bearers. Bad experiences with pruning are partly due to the common practice of cutting back. If bearing trees require pruning, this should nearly always be cutting out (thinning).

6 Control over the growth rhythm

As explained in Chapter 3, the large majority of branched fruit crops lay down floral buds on resting twigs. In many tropical regions these crops are not exposed to sufficient stress to curb and synchronise shoot growth. As a result they tend to flower and fruit poorly and this aggravates excessive, non-synchronous shoot growth, also during the period when floral buds for the next crop should be laid down.

It was also noted that rather than excessive flushing, extended twig rest may occur, particularly in older trees. Where this happens, forcing bud break to obtain an early harvest can be very beneficial.

In this chapter, growing techniques are discussed to overcome this problem. First, treatments are presented that strengthen and extend the natural stress, in order to curb late flushing towards and during the period that floral buds are laid down. Second come techniques to force bud break, ensuring synchronous flushing. These techniques are also used to advance flowering in case twigs rest much longer than necessary to form floral buds.

6.1 Increasing stress for better flowering

Traditional soil/root treatments

Traditional methods to reinforce environmental stress include:

- Root pruning
- Removal of the top soil under the tree
- Pouring salty water in a shallow ditch surrounding the tree.

The principle is to strengthen the effects of the dry season, making it more difficult for the roots to absorb moisture. Roots in the topsoil are cut with a spade near the drip line of the canopy. Salty water is also poured along the drip line. Removal of topsoil starts close to the trunk; the soil is hoed towards the drip line.

These methods are laborious and crude (roots are damaged; salts need to be washed out during the wet season). A more delicate alternative might be to remove the mulch under the tree row by raking it to the drip line. Young, vigorously growing trees in particular may benefit from this treatment. If the trees have been mulched generously in the previous years, many roots will be found near the soil surface, just under the mulch. Exposing these roots towards the start of the dry season should help to quickly stop shoot growth, after which the mulch can be spread again.

In Thailand the fluctuating ground water table is used to prune roots. Towards the end of the wet season the rising ground water table kills submerged roots.

Girdling

Girdling the tree trunk (also called 'cincturing') is a widely used traditional method. A ring of bark 3 to 12 mm wide is removed to block the flow of carbohydrates from the leaves to the roots. Carbohydrates are building material for new cells; broken down with oxygen they also provide energy for the life processes. Stopping this flow hampers root growth and reduces the supply of water and nutrients to the shoots. This should suppress further flushing, keeping the twigs at rest so as not to disturb floral development.

In lychee, 3 mm-wide rings cut with a hacksaw delay flushing by about 2 months. Wider rings – about 1 cm – are common in mango and apple; special knives are sometimes used to cut such wide rings. Striking improvements in flowering and yield, linked with suppressed flushing and much shorter shoots, have been obtained in young mango trees by tying a length of twine tightly in the girdle. The wound should begin to heal within about 6 - 8 weeks; otherwise the branch – or tree – may not recover. Thus girdling is risky and requires experience with the tree crop concerned. Tying a strip of polythene around the trunk to cover the girdle speeds up healing of the wound (olive). To reduce the risk (some of) the major limbs may be girdled instead of the trunk.

Alternatively, you may experiment by cutting 2 semi-circular girdles, one a bit higher on the trunk than the other, as shown in figure 14. This is a bit like a common traditional method, also shown in figure 14, to ‘calm down’ seedling trees that fail to come into bearing: a series of slashes are made with a machete in a spiral around the trunk.

Girdling is mainly suited to treating young trees that should come into bearing. In that case you are anxious to obtain the first crop and girdling young trees does not demand much labour. If successful, the fruit load will limit shoot growth so that the treatment does not have to be repeated. Girdling should be timed to prevent flushing shortly before and during the formation of floral buds, say 2 - 4 months before the trees should flower. Your own observations about the flushing pattern in relation to blossom time should guide you in determining when to girdle.

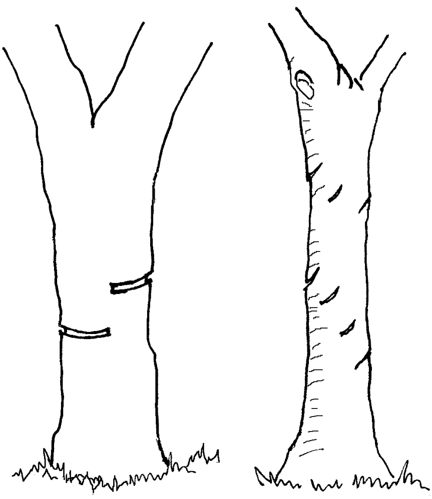


Figure 14: Semi-circular girdling cuts (left) and slashes spiralling around the trunk (right)

Pruning

In a few crops removal of the shoots of a flush occurring within the last few months before bloom is becoming common practice. The examples are limited to lychee, carambola and some mango cultivars growing in the subtropics. In the tropics, flushing while floral buds are supposedly laid down is much more of a problem. Therefore, cutting out of such an untimely flush deserves to be tried in the tropics too, in particular for fruit crops that flower on terminal buds, such as mango and rambutan.

Growth retardants

Growth retardants are chemicals that inhibit growth-promoting hormones in the plant. They offer a direct way to curb shoot growth. Several growth retardants have been used in fruit growing; the only one that caught on in the tropics is paclobutrazol, tradename Cultar®. Paclobutrazol not only inhibits shoots growth, it also promotes flowering, the ideal combination of properties! However, the uses of paclobutrazol are rather limited, because its application is complex. It works best when applied to the soil, but that makes it difficult to predict how much will reach the roots. Too high a dose results in malformation of shoots and inflorescences. Moreover, paclobutrazol is persistent; its effects carry over in the next year, making it even more difficult to set the right dose in annual treatments. In many countries it has not been registered for use on fruit crops.

New growth retardants are coming on the market, which supposedly are safer and simpler to use. Time will tell whether these new products are indeed better.

6.2 Fitting crop care operations in the growth cycle

Where the above treatments are successful in establishing a clear-cut annual crop cycle, it becomes possible to time all the other crop care operations more precisely. This is shown in the crop cycle for mango growing in a monsoon climate with wet and dry seasons of about 6 months each (figure 15). The curves represent elements of the growh rhythm: flowering, flushing of shoots and fruit growth in the course of the year.

The cycle starts with the dry season flush, in which first flower buds open, quickly followed by flushing shoots. As indicated at the bottom of figure 15, irrigation from the start of this flush till the onset of the rains is a great bonus. It makes application of fertiliser effective (fertilising dry soil is useless), so that the flush and fruit set can be supported with water and nutrients.

A good crop of growing fruit suppresses flushing as well as root growth, even if the trees are watered. Early cultivars can be harvested before the rains start, but late cultivars may need protection against anthracnose. Early in the wet season another fertiliser dressing will stimulate the post-harvest flush; pruning should take place before this flush starts. There may be some more shoot growth, but flushing towards the end of the wet season should be discouraged, for instance by girdling, to give the twigs time to lay down floral buds for the next crop.

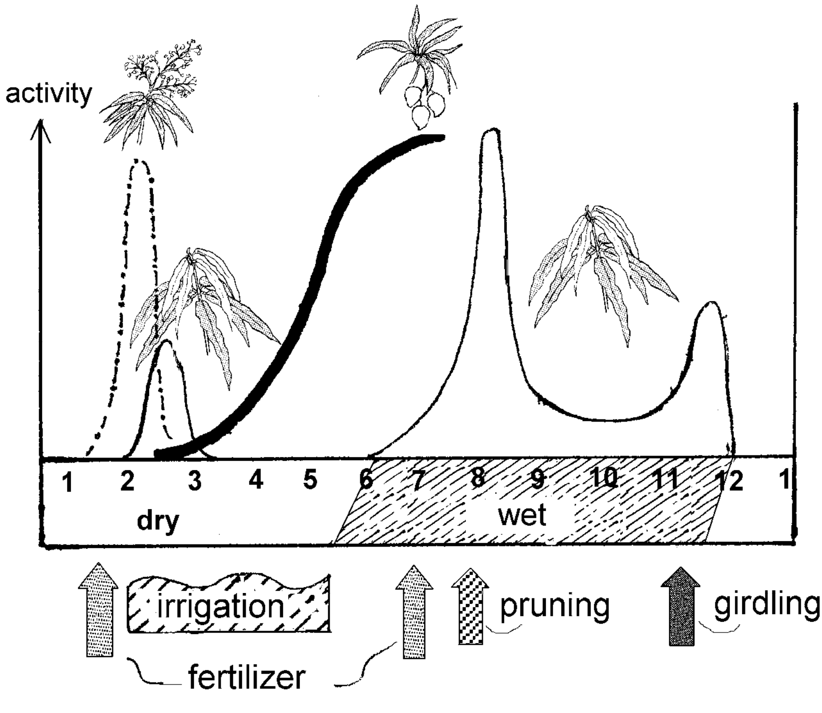


Figure 15: The growth rhythm of mango in a monsoon climate, and timing of crop care to strengthen the crop cycle

Making sketches as in figure 15 for your own trees and growing seasons could be very worthwhile. It may help to formulate the ideal crop cycle in the course of the year and the correct timing of measures to control growth. For instance, if carambola or rambutan produce two crops in a year, you may wish to increase the one crop at the expense of the other. If so, you should be very clear in your mind about what treatments to try and how to time them. But sketches of course can only be realistic if you keep a keen eye on the behaviour of your trees through the seasons.

6.3 Forcing synchronous flushing/flowering

Synchronous post-harvest flush

If the treatments in the previous paragraphs are successful, leading to good flowering and fruiting, shoot growth will be minimal while the fruit is growing. This leads to a synchronous post-harvest flush, the ideal way for a fruit grower to ensure synchronous flushing!

Interruption of irrigation

Growing the crop under irrigation in a relatively dry area offers excellent opportunities to control the annual crop cycle. Shoot growth can be curbed by withholding irrigation for 5 - 10 weeks. Resumption of irrigation ensures synchronous bud break and flowering of crops such as citrus and mango. If the dry season is long, it is even possible to set part of the orchard dry while the rest is still watered so that this part can produce an early crop, the rest being harvested later.

Rest-breaking chemicals

Growers in the Philippines discovered that several mango cultivars flower within a few weeks after being sprayed with potassium nitrate, a foliar fertiliser, provided that trees are treated after the last flush has matured. It is not quite clear whether the treatment brings existing floral buds into bloom, or induces initiation of floral buds. However, bloom can be advanced by several months. This, and the fact that mango yields in the country doubled to about 10 ton per ha within 10 years after the use of potassium nitrate caught on, suggests that the

chemical does promote flowering. Although potassium nitrate has been less effective in other countries and on other fruit crops (and other mango cultivars), its potential to force flowering is now widely accepted.

A range of other chemicals has been used to force bud break. In East Africa thiourea was already used in the 1970s on fruit crops from the temperate zone, such as apple, pear and plum. Thiourea acts mainly on leaf buds, whereas potassium nitrate is effective on floral buds. In Thailand mangoes were treated with thiourea to force a synchronous flush. As soon as the shoots matured, paclobutrazol was applied to suppress further shoot growth and to induce flowering.

These other rest-breaking chemicals are not used much, however. It is hard to set the timing and concentration of the treatments correctly, since their activity depends on the weather following application as well as on the condition of the trees. Dieback of shoots following application can be quite severe. Moreover, in most countries these chemicals have not been registered as rest-breaking agents.

Nevertheless rest-breaking chemicals are mentioned here because new products, such as Waiken® and Armobreak®, are being tested. These are applied mixed with a rest-breaking agent and the mixture appears to be more effective at much lower concentrations of the rest-breaking chemical. This should make application cheaper and safer (for both grower and trees).

Defoliation

Perhaps you have seen how a healthy tree, when all its leaves have been eaten by a plague of caterpillars or locusts, responds with a general flush of new shoots. This observation has led to the use of defoliation as a means to force synchronous flushing to start a new crop cycle. Defoliation was first used on fruit crops from the temperate zone, such as apple, peach and grape. These crops depend on winter cold to break bud dormancy. In the tropics they only grow in the highlands, but even in cultivars with low chilling requirements, bud break is usu-

ally poor. At elevations above 1200 m rest-breaking chemicals, mentioned above, are sometimes used to force bud break.

At lower elevations apple trees are defoliated to force bud break before the floral buds have gone dormant. In this way the crop cycle is shortened to about 6 months so that two crops are produced per year. Grape produces two crops per year in a similar way. Trees can be defoliated by hand, but rest-breaking chemicals are sometimes used to scorch the leaves; most grape leaves are removed by pruning.

Defoliation exhausts the tree making intensive crop care (irrigation, manuring, crop protection) essential. Even so the forced trees tend to age quickly, especially if the crop cycle is shortened. Promising reports of shortened crop cycles in truly tropical crops (guava, mango) have not been substantiated by wider adoption of the techniques, but trials with guava have been successful in several parts of the tropics (see figure 16).

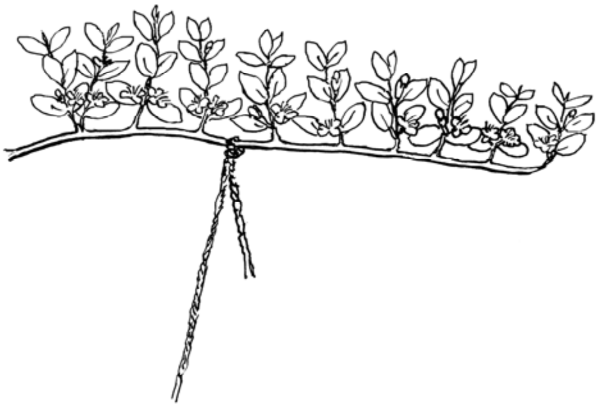


Figure 16: Twig of a young guava tree, tip-pruned, tied down and defoliated, showing new shoots about to flower along its entire length

7 Pollination and fruit set

7.1 Flowering habit

Without flowers there will be no fruit. Only pistillate (= female) flowers set fruit. Staminate (= male) flowers produce the pollen needed to pollinate pistillate flowers. Perfect (= hermaphrodite) flowers have both pistils and stamens. Figure 17 shows the parts of a perfect flower.

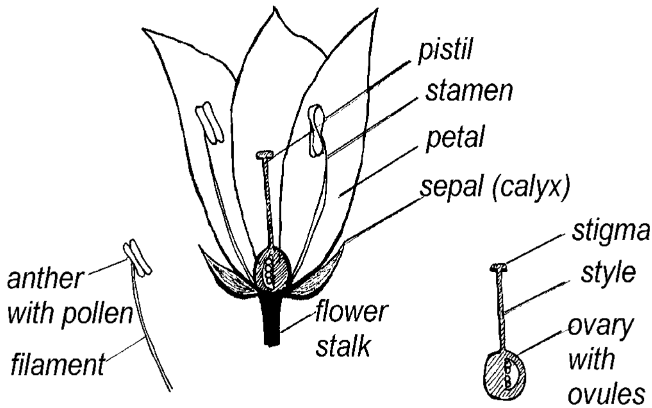


Figure 17: The flower and its parts

Flowers borne singly or in small inflorescences (as in soursop, sugarapple, guava) are usually perfect, but inflorescences with many flowers (like those in mango and rambutan) often contain imperfect flowers as well. Strict segregation of the sexes is found in papaya for instance: male and female inflorescences are on separate plants. This segregation of the sexes on separate trees, which prevents self-pollination, is called dioecy. Jackfruit and breadfruit are examples of male and female inflorescences borne on the same tree (monoecy).

In banana and coconut flowers of both sexes are found in the same inflorescence, the staminate flowers at the tip and the pistillate flowers at the base. The large mango inflorescence bears both staminate and perfect flowers.

The flowering habit of the fruit crops in this Agrodok is presented in the Appendix. Flowering habits are rather varied. There are, for instance, papaya cultivars in which all the plants bear fruit because they are either female-flowering or bear perfect flowers. You can recognise these cultivars because the perfect flowers are on long stalks (like those of male plants) and the fruit is more elongated.

Flowering habit not only varies depending on the cultivar, it also varies from year to year. The percentage pistillate flowers in coconut or that of perfect flowers in mango may be much higher in one year than in another, generally it is higher when growing conditions have been favourable. Growing conditions also influence flower quality. A healthy tree of moderate vigour bears strong flowers, the stigma being receptive for pollination over a longer period of time to improve fruit set.

7.2 Pollination

Flowers need to be pollinated in order to fertilise the ovule(s). The fertilised ovules become the seeds; they produce hormones that ensure that the flower sets fruit and that the fruit grows. In a few cases fruits grow even without the stimulus from the seeds, so-called parthenocarpic fruit. Examples include pineapple, banana, and some cultivars of other fruits, e.g. seedless guava and mandarin.

If the pollen comes from the same flower or from a flower on the same tree this is called self-pollination. If the pollen comes from a tree with a different genetic make-up, this is called cross-pollination. Nowadays many fruit crops are cloned. Since all the plants in a clone have the same genetic make-up, pollination within a clone is still self-pollination.

Continued self-pollination in successive generations leads to inbreeding, meaning a narrowing of genetic variation. As a rule this leads to reduced vigour and fitness. This may be the reason why in many plants form or function of the flowers makes self-pollination difficult or impossible, thus favouring cross-pollination. One arrangement is that the pistil is not receptive at the time that the stamens of that flower shed their pollen, another that the stamens are too short for the anthers to shed the pollen on the stigma. Self-pollination is impossible if the genetic make-up of the pollen is not compatible with that of the pistil, so that the pollen tube cannot grow down the style towards the ovules (e.g. pineapple).

Apart from these adaptations to limit self-pollination, plants generally produce more fruit following cross-pollination. If you grow a single clone of a fruit crop, nearby seedling trees of that species may provide the pollen to cross-pollinate the flowers on your trees. However, it is generally safer to grow a few clones together in your orchard.

A good pollinator has *VIABLE* pollen that is genetically *COMPATIBLE* with the cultivar to be pollinated and *FLOWERS AT THE SAME TIME*. Unfortunately this information is not available for most tropical fruit crops. Therefore it may be wise to plant at least three cultivars together and to try to make sure that the flowering periods of these cultivars overlap. Should one of the three prove a poor pollinator, chances are that the other two between them can assure cross-pollination of all three cultivars.

Pollen may be transported by wind, but to carry the pollen from tree to tree most tropical fruit crops rely on insects (honey bees), a few also on birds (humming birds for pineapple in South America), or bats (baobab, durian). The flowering habit and pollen transfer in some minor fruit crops has not yet been described. Flowering and pollination of several important fruit crops – such as avocado, rambutan, oriental persimmon – are too complex to be explained here. But these aspects are so important that you should gather the information yourself, ei-

ther from knowledgeable people, publications, or your own close observation of the flowers on your trees and their visitors.

Dioecy presents a serious problem to the grower, especially where the crop is grown from seed, as in the case of papaya, salak, rambai, Amazon tree grape, butter fruit tree and oyster nut. Half the seedlings will be male, but you cannot identify them until the trees flower, at which time you can remove the ‘males’, leaving only 1 or 2 out of 20 to pollinate the ‘females’. It means you have wasted years to raise these trees and are left with a plantation full of gaps. The only elegant solution is to adopt clonal propagation: plant a female clone and interplant with a compatible male clone in 5 – 10 % of the tree positions.

It is clear that cross-pollination is an important issue in fruit growing. The grower should plant alternate rows of different cultivars or, if the pollen comes from male trees, interplant these trees in the rows. A windscreen may be needed to create shelter for the insects during the flowering season (often hot, dry and windy). A beekeeper can assist by placing hives in the orchard. Agrodok 32, ‘Beekeeping in the tropics’, gives more information. In some cases the grower has to lend a hand; hand pollination is often practiced on custard apples, passionfruits and salak.

The Appendix gives brief information about the way in which pollination is effected in the listed fruit crops.

8 Crop protection

Crop protection practices are linked to the cropping system. The use of commercial pesticides is by and large limited to orchards and large plantations. In orchards of small trees, such as mandarin, guava or apple, pesticides are often used to excess. Intensive crop care drives up the cost so much that the grower cannot risk crop failure; he tries to protect his trees with whatever pesticide is recommended (and available). Routine spraying, without regard for the level of infestation, is common. In this way the natural checks and balances between pests and their predators in the orchard are disturbed, so that one treatment breeds the need for the next one. Moreover, there are serious health risks: for the grower who handles the materials and is exposed to the spray drift; for the consumers when they eat the fruit; and for the creatures living in the soil and nearby water courses that become polluted.

Tall trees cannot be treated with small (knapsack) sprayers and even spraying of medium-sized trees in orchards (e.g. rambutan in Thailand, mango in the Philippines) is the exception rather than the rule. If the orchard consists of a mixture of fruit crops it is hard to avoid pesticide drifting onto non-target trees.

The scattered trees in home gardens, backyards, along field borders and watercourses do not lend themselves to being sprayed with pesticides. Several traditional crop protection measures are practiced in home gardens, but mainly on small plants and in nursery work (e.g. use of wood ash and plant extracts). On the trunks of tall trees in the garden one often sees collars, made of metal sheeting or thorny branches, to stop rodents from climbing the trees. Large fruit, such as jackfruit, may be bagged to protect it against insects, birds and bats. Smaller fruit (e.g. guava) is sometimes bagged too, in particular to prevent fruit flies from laying their eggs there. On the whole home gardeners hope that the rich mixture of plants will make it more difficult for pests or diseases to become a plague, but they also accept substantial losses as a fact of life.

8.1 Limiting use of pesticides

It is now realised that the use of pesticides should be drastically reduced by:

- Abandoning routine treatments
- Replacing broad-spectrum pesticides by products that kill the target pest but do not harm other organisms.

This last approach is not easy, because you may find that the choice is limited to pesticides used in the major cash crops in your area, such as cotton or coffee. Selective pesticides for your crops may not be available.

Stopping routine spraying is also a problem: to be able to spray at the right moment, the grower must first become familiar with pests and diseases and their life cycles. These life cycles are usually tied to the seasons and, especially for pests and diseases that complete their entire life cycle on the tree, to the growth rhythm of the tree. Many diseases, for instance, become rampant during the wet season: cankers, such as pink disease (*Corticium salmonicolor*) can be found in many fruit crops throughout the year, but they are spread mainly by rain. Thus cankers can be controlled to a large extent by cutting out and burning affected branches before the end of the dry season, so that there are few sources of infection at the beginning of the rains.

Mango hoppers suck the young shoots and especially inflorescences; they can ruin even a heavy bloom. Control using insecticides is difficult and depends on correct timing at the beginning of the flush. This is only possible if all the trees flush simultaneously. Controlling the crop cycle to ensure simultaneous flushing, flowering and fruiting helps to time the treatments of pests whose life cycle is linked to that of the tree (e.g. tip borers killing young mango shoots, stink bugs puncturing the flowers of longan, and fruit borers and fruit flies on a number of crops). The result is better control with fewer treatments, and minimal disturbance of the natural environment.

Limiting the use of pesticides requires increased attention on other ways to tackle pests and diseases:

- Hygiene
- Biological control: using other organisms to control pests and diseases
- Disease-tolerant or disease-resistant cultivars or rootstocks.

Hygiene

Hygiene comes first. If you buy citrus trees in the nursery infected with scales or mealy bugs, you fight a losing battle against these pests. Start clean, stay clean!

The above example of cutting out and burning cankers of pink disease before the rains come is also a matter of hygiene: clean up, choosing the right moment. Bagging fruit on the tree, also mentioned above, is laborious but can be very worthwhile where fruit flies, bats or birds cause much damage and unblemished fruit commands a high price. (Certain guava and mango cultivars are harvested and eaten green, before the fruit fly maggots hatch from the eggs.)

Ants carry immobile insects around (also aphids, leaf hoppers and some other insects) to young shoots, in order to milk them for the honeydew that they secrete. Ants also protect these insects against their natural enemies. So controlling ants is important. Sticky paper collars fixed around the tree trunk catch the ants (and some other wingless insects which try to climb the tree). If an insecticide is used against ants it needs only be sprayed on the trunks.

Hygiene also means checking plants that are alternative hosts for a pest or disease. This may be difficult, because information is lacking or because you cannot do much to control alternative hosts. One practical example is kei apple, a very useful hedge plant in the highlands but also a host for citrus fruit flies. All the grower has to do is to trim hedges regularly so that they will not bear fruit. It is advisable to collect fallen fruit because it is often infected by pests and/or diseases.

However, this is a lot of work, because it has to be done frequently and each time the fruit has to be buried in a pit under a thick layer of soil.

Biological control

Biological control has great potential, because every organism is subject to diseases and has natural enemies. Fungi and bacteria as well as insects suffer from viruses and other bacteria or fungi. Insects are also preyed upon by predators.

Biological control is expanding, although not as fast as it should. Tropical fruits also benefit. Citrus growers, for instance, can learn from their colleagues in the subtropics, where the number of treatments with pesticides has been drastically reduced in favour of biological agents, restoring natural checks and balances. Leaf miners in citrus for example, a very stubborn pest in spite of frequent spraying, are less of a problem where these treatments are minimised. Aphids have a range of predators: parasitic wasps, larvae of ladybirds, hoverflies and lacewings. Parasitic wasps and ladybirds are raised and released in orchards in large numbers to control aphids.

Interesting forms of biological control came to light when trees were successfully treated with Surround® to reduce heat stress and sunburn in hot and dry conditions. Surround® simply consists of fine clay particles that give the tree a reflective coating when sprayed with water. Treated trees suffered less from a wide range of pests, including maggots, leafhoppers, caterpillars and psyllids. The white film on the leaves confuses or repels some insects and acts as a barrier preventing other insects from laying their eggs. A simple product opening up new possibilities in crop protection!

Disease-tolerant cultivars

In several fruit crops disease-tolerant or resistant cultivars are becoming available. Even rootstocks can play a role. Rootstocks tolerant to root rot are recommended for avocado, rootstocks resistant to the Tristeza virus for citrus. Purple passionfruit can be grafted on seed-

lings of yellow passionfruit that are resistant to soil-borne Fusarium fungi. However, most of these tolerant/resistant cultivars and root-stocks have their origins in the subtropics. For the truly tropical fruit crops similar material is generally lacking.

9 Harvesting

9.1 Mature or ripe fruit?

When a fruit is fully grown it is said to be mature. Hence, a mature fruit does not grow anymore, but it continues to ripen. In some mature fruits the ripening process includes a brief phase of accelerated ripening (the ‘climacterium’). These climacteric fruits can be harvested at any time between the mature and ripe stage. If they are harvested as soon as they are mature, the ripening period can be used to transport and market the fruit, and then it may still require a few days in the fruit bowl before it is at its best. Moreover, if the fruit is refrigerated or kept in controlled atmosphere (for instance on a banana boat) before the climacterium is reached, ripening is delayed until the fruit comes out of storage. In this way the so-called ‘shelf-life’ of climacteric fruit can be extended for weeks or months, facilitating long-distance trade.

Some crops have mature fruits that ripen gradually, at a steady pace (non-climacteric fruits). These fruits should not be harvested before they are ripe, because the ripening process stops as soon as they are picked. The taste, flavour and texture of an unripe fruit do not improve after harvest. Harvesting at the ripe stage implies that the fruit should be eaten soon; there is little time for transport, trade and display in the market/shop. On the other hand the harvest time may range widely, depending on the preferred quality. For instance, most people like a sweet mandarin, but if you prefer a more acidic taste you can harvest much earlier. The slow ripening is sometimes used to ‘store’ the fruit (e.g. citrus and grapes) on the tree. Examples of fruit crops in both groups are given in the Appendix.

Growers are inclined to harvest early, in order to minimise losses by theft, birds, bats, fruit flies, and so forth. Seasonal fruit is often harvested early, in order to be sold before others flood the market. However, picking immature or unripe fruit is bound to spoil your reputation, as it puts off those who eat the fruit. Nothing can beat the quality

of fruit that has ripened on the tree and is eaten as soon as it is picked; this is even true for climacteric fruits. It is the home gardener who has the privilege of enjoying fruit at its best!

Certain fruits, for instance mango, guava and papaya, may be harvested green (immature) for use as a vegetable. In this way the usefulness of the fruit is extended beyond the normal harvest season.

9.2 Harvest methods, harvest indices

The harvest crowns the work of the grower. But does it really? Clearing the crop on a tree in a single picking is quite common and the harvesting methods are far from delicate. Too often, looking at the produce in the baskets, one wonders: is this what the grower has been working for all year? Those few quality fruits that are unblemished, at the right stage of ripeness, and so many fruits with one defect or another?

There are two main reasons why tropical fruit are often of poor quality:

- Maturity or ripeness is hard to judge
- Harvesting fruit on tall trees is difficult.

Fruit is mature when it is fully grown, but growers do not actually measure the fruit at intervals to find out whether they are still growing. A useful guide for the harvest date is the number of days from bloom to maturity. Growers also have to gain experience in judging the shape, size, ground colour or sheen on the fruit as indicators of maturity (see Box).

Ripeness is generally easier to judge than maturity, because the fruit changes colour, becomes fragrant or emits a hollow sound when tapped (because the seed cavities are fully formed, for instance in durians and jackfruits). But as said before, it is also a matter of the taste. So citrus growers may pick a few fruits at intervals and start the harvest when the sugar-to-acid ratio is acceptable. There are criteria

for ripeness of the flesh that can be measured with suitable equipment. Supermarkets, for instance, may only accept fruit that exceeds a certain specific gravity, sugar-to-acid ratio or soluble solids content.

Maturity indices for mango and durian

Maturity of mangoes is quite hard to judge and if picked when immature the fruit tastes poorly and shrivels in the end. Growers in South-East Asia take the number of days from bloom to harvest as a starting point, e.g. 84 days for the Philippine ‘Carabao’, 90 days for the Indonesian ‘Arumanis,’ and 100 days for the Thai ‘Nam Doc Mai’. They also look at the development of the ‘shoulders’ on either side of the stalk and the ground colour of the fruit. If the fruit is mature the stalk should snap easily following a slight pull. The stalk should be trimmed so that it does not puncture other fruit in the basket. A copious flow of resinous sap from the cut also indicates immaturity.

In South-East Asia durians are usually allowed to drop from the tree when ripe, the trees being very tall. On hearing the thud of a fallen fruit, people quickly gather it before animals get to it, attracted by the smell. Keen growers tie the fruit stalk to the branch with a string so that it does not drop; it has to be collected where it hangs. This method is as laborious as it is ingenious and shows to what lengths people will go to harvest top quality fruit!
In Thailand good crops greatly reduce tree vigour and picking mature fruit by hand is feasible because the trees remain small. Skilled pickers use a range of criteria to judge maturity. Starting with the number of days lapsed since full bloom, they may also consider: colour, elasticity and separation of the spines; the odour of the fruit; the sound heard when the fingertips are run through the furrows between the spines; and changes in the fruit stalk. Whereas ripe, fallen fruit has to be consumed as soon as possible, the mature fruit of Thai cultivars is fit for export.

The large size of most tropical fruit trees makes selective harvesting (several picking rounds to harvest only mature/ripe fruit) impractical. Moreover, trees and fruit suffer from crude harvesting methods:

- The picker climbing the tree, pulling branches with a hook to get hold of the fruit
- Harvesting from the ground with a bamboo pole with a basket attached to the top to hold the fruit.

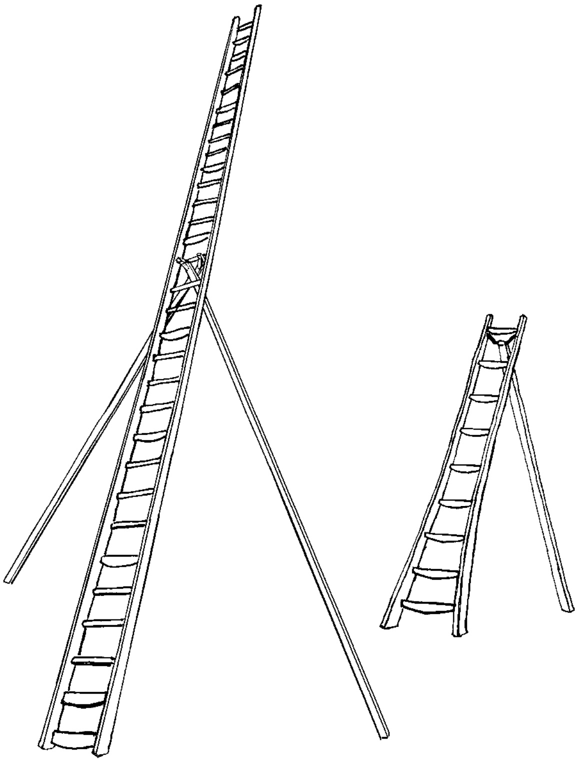


Figure 18: Tripod ladder and long ladder with props

Climbing is rather inefficient because most fruits are borne on the periphery of the canopy. Picking from the ground proceeds at snail's pace and it is hard to judge the ripeness of the fruit. Ladders are the appropriate equipment (see figure 18), but long ladders are costly. Moreover, pickers must learn to handle ladders, in the first place to reduce the risk of accidents. Long ladders can be propped with 2 poles hooked crosswise under a rung; this brings fruit at the edge of the canopy within reach. However, to harvest more fruit, of better quality, with less effort much smaller trees are needed.

9.3 Handling and marketing

In commercial fruit production, growing the fruit is the lesser half of the job. The greater half consists of post-harvest handling and marketing, implying that your income from fruit depends largely on the folowing aspects:

- sorting and grading
- washing, protection against infection and deterioration
- packing
- storage
- transport
- trade channels and market outlets
- quality criteria for fresh produce and for supplies to processers.

A discussion is beyond the scope of this booklet.

10 Layout and establishment of the orchard

This is usually one of the first subjects in books on fruit growing, but in fact all the other subjects should be clear in your mind before you start planning the layout of an orchard. You should take into account:

- Differences in vigour between cultivars
- Measures to control tree vigour (drought, root pruning, girdling, etc.)
- Requirements with regard to cross-pollination.

10.1 Tree spacing

Orchards are traditionally planted ‘on the square’, e.g. 10 x 10 m for mango. This is all right for large seedling trees with their immense canopies. If smaller tree size allows doubling the number of trees per ha to 200 (approx. 7 x 7 m), other planting patterns may not be advantageous. But if 400 trees or more can be planted per ha, the trees should remain so small that you can allow them to form a closed row or hedge. This means that, at 400 trees per ha, instead of a spacing of 5 x 5 m on the square, a spacing of 6 x 4 m, i.e. *ROW CROPPING*, becomes attractive. Sufficient light should penetrate the hedge to produce good quality fruit even on the lowest limbs.

The square planting pattern is based on the notion that all trees grow equally well and that you can fairly accurately predict the size of the mature trees. Both notions are false. There is usually much variation in tree size, even in a single cultivar. Also, it is quite common for trees to remain much smaller or to grow much larger than anticipated. A succession of a few good crops as soon as the tree comes into bearing greatly helps to limit tree size.

As shown in figure 19 the open fringe around each tree planted on the square has become an open alley in the row-cropping model. The closer spacing in the row means that a more vigorous tree can make

up for a weaker neighbour. If growth is disappointing, the trees should still fill the rows and intercropping in the alleyways can be continued for a few more years. If tree vigour is excessive, the alleyways serve as an outlet for some time. And if vigour cannot be controlled, grubbing half the trees will result in a new row alignment with a spacing of 8 x 6.25 m.

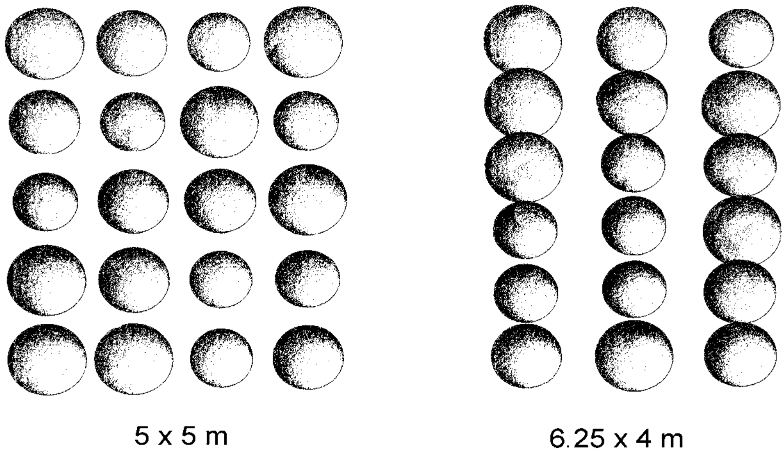


Figure 19: Planting on the square compared with row cropping, both at 400 trees per ha and similar variation in tree size

In comparison with square planting row cropping is a very flexible tree arrangement. Row cropping also lends itself to planting along the contours of a slope, or across the direction of the prevailing wind on a windswept site. Row cropping is very much on the increase now that growers are trying to limit tree size through clonal propagation and other methods.

When using clonal planting material or named cultivars, it is advisable to plant several cultivars side by side in the orchard in order to:

- Spread the risk of a cultivar not living up to your expectations
- Facilitate cross-pollination.

Lack of vital information makes it risky to concentrate on a single cultivar. For most crops, the available information about cultivars is largely limited to the *FRUIT*: shape, colour, taste, shelf life, etc. However, for the grower information about the *TREE*, such as vigour, productivity, disease tolerance, is just as important. Textbooks have little if anything to say about these tree characteristics, in part because they are strongly influenced by local growing conditions (and in budded or grafted trees they are determined by the rootstock as well as the cultivar). Hence, unless there is sufficient local information, the right spacing is a gamble, yield predictions are guesswork and diseases and pests may play havoc with the trees.

So you have to look around you, consult extension staff, other growers and nurserymen. If you are not sure, just plant rows 1, 3, 5, 7, etc. with the main cultivar and, for instance, another cultivar in rows 2, 6, 10, etc. and a third cultivar in rows 4, 8, 12, and so on. Planting three cultivars in this way will create good conditions for cross-pollination. Moreover, weak growth in one row may be compensated by more vigorous growth in the next row (and if you know this beforehand you can adjust spacing within the row to the vigour of the cultivar). Crop care is facilitated because within a row the requirements with regard to pruning, crop protection, harvesting, etc. are the same.

10.2 Orchard establishment

Tree growth during the early years largely determines when the trees come into bearing. As explained in Chapter 2, in most instances growth of bearing trees needs to be curtailed to balance it with fruiting. If this is the case you can only safely boost tree vigour during the pre-bearing years. A robust tree frame with well-spaced limbs formed during several, prolonged flushes in the first 2 years, is an asset for life. It is why looking after the tree during the first few years is emphasised here.

Textbooks generally recommend digging large planting holes (e.g. 40 x 40 x 40 cm) well in advance of the planting season, keeping topsoil

and subsoil separate, so that when the tree is planted the topsoil can be spread over the roots first. This is fine if you have time, but as a rule labour can be better spent on mulching and/or watering the young trees.

If the trees are to be tied to a stake, it is advisable to set out the stakes first. Plant the tree on the lee side of the stake and not on the windward side, so that the tree will not rub against the stake. Dig a hole big enough to accommodate the roots; for bare-rooted trees the roots may be spread in a V-shaped hole extending on both sides of the stake, as in figure 20. Make sure that the union of grafted or budded trees is well above ground level, also after the soil has settled, to prevent the scion from striking root.

Figure 20: V-shaped planting hole and stake

Growers often lose interest in their trees during the long years waiting for the first crop. This is understandable, but it is also a big mistake. Having invested in good planting material and careful planting, you should go on investing in your trees. Pamper them with a generous mulch and if necessary protect them against browsing cattle and strong wind, provide temporary shade and apply water. If the soil can be kept moist, the young trees will also respond well to manure or fertiliser.

Young trees need attention almost daily. Climbing weeds need little time to reach the top of the newly planted tree. Root suckers and side shoots that emerge too low on the trunk waste the tree's energy and need to be removed. If done early, the side shoots can simply be brushed off (advantages: little labour required, little growth wasted).

Crickets, caterpillars, night-feeding beetles, etc. can quickly finish the leaves on a small tree. Look closely; often shading material (set up to protect the young tree against the sun) hides the first indications of trouble. Frequent inspections can nip infestations in the bud: crickets and caterpillars can be caught by hand. This may sound primitive, but a larger cricket or caterpillar is hard to poison with insecticide, because it eats far less in relation to its body size than a tiny one. Hence, treatments with insecticides also require frequent rounds for timely control.

Set your standards high. Do not be satisfied if all trees survive so that there is no need to fill gaps. Your aim should be uniform, vigorously growing trees that hold the promise of rich rewards.

Appendix: Horticultural traits

Explanatory notes

Fruit crops are listed alphabetically per family, to show which crops are closely related, having common characters. The table gives traits of the flowers (including compatibility in pollination) and the fruit. Common propagation methods and horticultural status are also given. The number in the first column corresponds to the bold number in the Index.

Key

Flower traits	
perf	Flowers perfect (hermaphrodite)
mix	Flowers of different sex (e.g. male or female; male or perfect) in the same inflorescence
mono	Male and female flowers in separate inflorescences on the same tree (monoecy)
di	Flowers of different sex (e.g. male-flowering or female-flowering) on separate trees: dioecy.
Pollination	
x	Flowers self-incompatible (cross-pollination essential).
y	Self-pollination unlikely (e.g. stigmas not receptive when pollen is shed).
s	Flowers self-compatible.
Fruit traits	
clim	Fruit climacteric, ripens after being harvested mature
n-c	Fruit non-climacteric, no further ripening after harvest
par	Fruits commonly seedless: parthenocarpy.
Horticultural status	
uni	Seedlings uniform, showing little variation; trees usually propagated from seed
sel	Clonal propagation recommended, but selection has not yet resulted in named cultivars.
Var	Selected mother trees used for propagation (through seed or clones); cultivars being named.
Cvs	Clonal propagation of named cultivars commonly practiced.
Brackets	
(…)	Trait applies only to some varieties or cultivars

Table 4: Fruit crops listed alphabetically per botanic family

Nr.	Common name	Flower traits	Polli-nation	Fruit traits	Hortic. status
Anacardiaceae					
1	cashew	mix		n-c	var
2	mango	mix	s	clim	cvs
3	ambarella	perf			sel
4	red mombin	perf	y	(par)	sel
5	yellow mombin	mix			sel
6	marula	di			sel
Annonaceae					
7	cherimoya	perf	y	clim	cvs
8	atemoya	perf	y	clim	cvs
9	sugarapple	perf	y	clim	cvs
10	soursop	perf	y	clim	uni
Bombacaceae					
11	baobab	perf			sel
12	durian	perf	(s/x)	clim	cvs
Bromeliaceae					
13	pineapple	perf	x	n-c par	cvs
Caricaceae					
14	papaya	di	x	clim	cvs
Ebenaceae					
15	persimmon (black)	mix (di)		(par)	var
16	persimmon (oriental)	(mix) di		clim (par)	cvs
Flacourtiaceae					
17	kei apple	di			
18	governor plum	perf			var
Guttiferae					
19	mangosteen	di			uni
Lauraceae					
20	avocado	perf	y	clim	cvs
Leguminosae					
21	tamarind	perf	s		cvs
Meliaceae					
22	santol	perf	y		cvs
23	langsat	perf		par	cvs
Moraceae					
24	breadfruit	mono	y	clim par	var
25	breadnut	mono	y		var
26	jackfruit	mono	y	clim	var
27	Amazon tree grape	di			

Nr.	Common name	Flower traits	Polli-nation	Fruit traits	Hortic. status
Musaceae					
28	banana, plantain	mix		par	cvs
Myrtaceae					
29	guava	per	(s/x)	clim (par)	cvs
30	grumichama	perf	s?	n-c	sel
31	pitanga, Surinam cherry	perf		n-c	sel
32	Java apple, wax jambu	perf	s?	n-c	var
33	Malay apple, pomerac	perf		n-c	var
34	jambolan	perf		n-c (par)	var
Oxalidaceae					
35	carambola	perf	(s/x)	n-c	cvs
Palmae					
36	pejibaye, peach palm	mix	y		var
37	salak	di (mix)			var
Passifloraceae					
38	giant granadilla	perf	y	clim	uni
39	purple passionfruit	perf	s	clim	var
40	yellow passionfruit	perf	y	clim	cvs
Proteaceae					
41	macadamia	perf	y		cvs
Punicaceae					
42	pomegranate	perf			cvs
Rhamnaceae					
43	Indian jujube	perf	x	(par)	cvs
Rosaceae					
44	apple	perf	(s)	clim (par)	cvs
45	pear, nashi	perf	x	clim (par)	cvs
46	peach, nectarine	perf	s	clim	cvs
47	plum	perf	x (y)	clim	cvs
48	loquat	perf	(x) y		cvs
49	strawberry	perf	(y) s	n-c	cvs
Rutaceae					
50	casimiroa, white sapote	perf,	(x) y		cvs
51	kumquat	perf			cvs
52	grapefruit	perf		n-c (par)	cvs
53	lime	mix	(x)	n-c (par)	var
54	mandarin	perf	(x/s)	n-c (par)	cvs
55	orange	perf		n-c (par)	cvs
56	pummelo	perf	(x)	n-c	cvs
Sapindaceae					
57	longan	mix			cvs

Nr.	Common name	Flower traits	Polli-nation	Fruit traits	Hortic. status
58	lychee	mix		n-c	cvs
59	rambutan	di (mix)		n-c	cvs
Sapotaceae					
60	caimito	perf	s		var
61	canistel, egg-fruit	perf			var
62	mamey sapote, sapote	perf		clim	var
63	sapodilla, chicosapote	perf	(y)	clim	cvs
Vitaceae					
64	grape	perf		n-c (par)	cvs

Further reading

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www.greenbeltmovement.org gbm@wananchi.com

TOFNET, Trees on Farm Network for East and Central Africa
Coordinator: World Agroforestry Centre (ICRAF),
POBox 30677-00100, Nairobi, Kenya
www.tofnet.org tofnet@asareca.org

WAFNET, West African Fruit Network
Coordination: Plant Genetic Resources Centre
POBox 7, Bunso, E/R, GHANA

Contact for commercial fruit crops:
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Taiwan 74199, R.O.C.
www.globalhort.org/index.html

Glossary

air layering	a form of layering in which a ball of soil in a polythene cover is wrapped around a girdle in the branch to be layered; after roots grow into the soil ball the layer can be separated
annual plant	a plant that completes its life cycle within one year
apomixis	reproduction by seed formed without sexual fusion, hence a form of cloning
axil	the upper angle between a leaf and the stem
biennial bearing	a more or less regular alternation of heavy and light fruit crops in successive years
biological control	crop protection using natural ways to control a pest or disease, e.g. by natural enemies, or barriers such as a net to exclude birds
botanical name	unique name, given by a botanist, under which the plant species is known
cambium	a layer of meristematic tissue between wood and bark with cells which divide to form more wood and bark
cauliflory	flowers borne on the trunk and/or large branches
cincturing	see girdling
climacteric fruit	a fruit which, if mature, ripens after harvesting
climacterium	a spurt in the ripening process of climacteric fruit
clone	a group of plants originating by vegetative propagation from a single plant and therefore having the same genotype
compatible	of cultivars as pollinators: capable of sexual union, and thus of forming seeded fruit; in budding/grafting: capable of forming a lasting stock-scion union

cross-pollination	placement of pollen on the stigma of a flower that is not of the same clone
cultivar (cv)	a cultivated variety, as distinct from a variety that exists in the natural vegetation
deciduous	a perennial plant that is leafless during a (brief) part of the year
dichogamy	flower in which pollen is released before or after the stigma is ready to be pollinated, thus preventing self-pollination
dioecious	bearing flowers of a single sex, male or female, and borne on different plants (dioecy)
dormancy	a state of rest of seeds or buds, prohibiting sprouting even under favourable growing conditions
embryo	the rudimentary plant within a seed
evergreen	bearing leaves all year long, because leaf change is gradual
floral bud	bud that is in the process of laying down flower initials
flower bud	unopened flower
flush	a brief period of rapid shoot growth, preceded and followed by a period of quiescence, even under favourable growing conditions
gene	the bearer of a single genetic trait, located on a chromosome
genotype	the genetic make-up of an organism comprising all its genes
girdling	removal of a narrow ring of bark from the tree trunk or the tree limbs to starve the roots; also called cincturing
harvest index	the harvestable produce as a fraction of the total biomass produced by the crop in a given year
hermaphrodite	bisexual; with stamens and pistil in the same flower

hormones	growth substances, produced in various organs and moving through the plant in small quantities to direct the growth processes in dividing cells
inbreeding	breeding by sexual fusion of pollen and egg cells of the same or closely related genotypes
incompatible	in pollination: not able to achieve sexual union; in budding or grafting: not resulting in lasting union between stock and scion
indeterminate	of shoot growth: not limited to expansion of leaf initials which where already present in the bud
inflorescence	the floral structure consisting of more than one flower
juvenile phase	the period between germination and the first sign of flowering
marcotting	see air layering
monoecious	with flowers of a single sex, male or female, but borne on the same plant (monoecy)
node	the point on the shoot where a leaf is borne
non-climacteric fruit	a fruit which must ripen on the tree because it does not ripen after being harvested
orthotropic shoots	upright shoots that mainly serve to increase tree size in trees that also have more horizontally growing (plagiotropic) shoots
ovary	the enlarged base of the pistil which contains the ovules and grows into the fruit
ovules	the immature seeds in the ovary before fertilization
parthenocarpy	the production of fruit without true fertilization and hence without true seed (fruit usually seedless)
perennial plant	a plant living for many years
perfect flower	a flower possessing both male (stamens) and female (pistil) organs

pesticide	a chemical used to control pests; selective pesticides kill only the target pest, broad spectrum pesticides kill a wide range of insects
pistil	the female part of a flower consisting, when complete, of ovary(s), style(s) and stigma(s)
pistillate flower	a flower with pistil(s) but lacking stamens
plagiotropic shoots	shoots growing more or less horizontal and bearing all or most fruit, contrasting with upright (orthotropic) shoots in the same tree
pollen	tiny grains discharged by the anthers, containing the male element
pollination	the transfer of pollen to the receptive stigma, if dry largely by wind, if sticky mainly by insects
polyembryony	the growth of two or more embryos in an ovule, resulting in more than one seedling emerging from the seed; only one of these may be a true seedling, the others are clonal
quiescence	rest of plant parts, when there is no outwardly visible signs of growth; in this Agrodok mainly used for buds between flushes
rootstock	the part of a budded/grafted plant below the union, bearing the roots; above the union is the scion
scion	the part of a budded/grafted plant above the union; below the union is the (root)stock
self-fertile	capable of fertilisation and setting seed after self-pollination
self-pollination	pollination with pollen from the same plant or plants of the same clone
self-sterile	not capable of sexual union and seed production after self-pollination
sexual reproduction	propagation by seed following pollination of the flower and fertilization of the egg cell

shoot	a young stem bearing immature leaves, at least near the tip
stamens	the male organs of the flower, each consisting of a filament and an anther
staminate flower	a flower bearing only stamens, no pistil
stigma	the tip of the pistil that receives the pollen
style	the part of the pistil connecting the ovary with the stigma
sucker	shoot emerging from an adventitious bud, usually on a root or the tree trunk
taproot	the root that first emerges from the seed and normally becomes the main root of a plant raised from seed
variety	a distinct type within a species which occurs naturally; in cultivation a variety is called a cultivar
water shoot	vigorous sucker with juvenile traits emerging on or close to the trunk, often following injury (e.g. from pruning)
whip	a long unbranched shoot

Index

The index lists crops alphabetically by their common names used in this Agrodok. For each crop the botanic name is given, and if the crop is still well known by a former botanical name, that name is included in brackets. Names *in italics* refer to crops not usually included in the commodity group fruit and nuts. A **bold** number is the crop's number in the Appendix.

Common name(s)	**Botanical name (Former name)**	Page; **nr** in Appendix
Africado; see Butter fruit tree		
Amazon tree grape	Pourouma cecropiaefolia	11,58; **27**
Ambarella, Great hog plum	Spondias cytherea (S. dulcis)	28;**3**
Apple	Malus domestica	13,24,25,30,37,40,41,46,48, 53,54,55,59,61;**44**
Areca palm	*Areca catechu*	
Atemoya	Annona cherimola x A. squamosa	34; **8**
Avocado	Persea americana	18,24,31,35,37,40,,57,62; **20**
Banana, Plantain	Musa	6,9,12,13,14,15,19,21,22,34, 37,56,64; **28**
Baobab	Adansonia digitata	57; **11**
Brazil cherry, Grumichama	Eugenia dombeyi (Eugenia brasiliensis)	**30**
Breadfruit, Breadnut	Artocarpus altilis (A. communis)	23,34,37,55; **24**
Butter fruit tree	Dacryodes edulis	32,58
Caimito, Starapple	Chrysophyllum cainito	**60**
Canistel, Egg-fruit	Pouteria campechiana (Lucuma nervosa)	11,24; **61**
Carambola	Averrhoa carambola	49,52; **35**
Cashew	Anacardium occidentale	24,36,37; **1**
Casimiroa, White sapote	Casimiroa edulis	24,31; **50**
Cherimoya	Annona cherimola	**7**
Chiku, Sapodilla	Manilkara zapota (Achras zapota)	24,28,34; **63**
Citrus	Citrus	18,23,24,31,37,38,40,41,45, 46,52,61,62,64
Clove	*Syzygium aromaticum*	30

Common name(s)	**Botanical name (Former name)**	Page; **<u>nr</u>** in Appendix
Cocoa	*Theobroma cacao*	23,27,34
Coconut	*Cocos nucifera*	15,16,19,20,21,22,34,56
Coffee	*Coffea arabica*	8,23,26,27,3,0,34,45,46,60
Custard apples	Annona species	24,25,27,58; **7,8,9**
Date palm	Phoenix dactilifera	15,21
Duku, Langsat	Lansium domesticum	**23**
Durian	Durio zybethinus	12,23,26,27,34,37,46,57,65, 66; **12**
Egg-fruit: see Canistel		
Giant Granadilla	Passiflora quadrangularis	**38**
Governor plum	Flacourtia inermis	**18**
Grape	Vitis vinifera	11,23,30,34,37,42,43,53,54, 58,64; **64**
Grapefruit	Citrus x paradisi	**52**
Great hog plum: see Ambarella		
Grumichama: see Brazil cherry		
Guava	Psidium guajava	12,19,24,54,55,56,59,61,65; **29**
Hog plum: see Mombin		
Indian jujube	Ziziphus mauritiana	24; **43**
Jackfruit	Artocarpus heterophyllus	23,27,34,37,55,59,65; **26**
Jambolan	Syzygium cumini (Eugenia jambolana)	**34**
Java apple, Wax jambu	Syzygium samarangense (Eugenia javanica)	**32**
Kaki: see Persimmon		
Kapok	*Ceiba pentandra*	34
Kei apple	Dovyalis caffra	61; **17**
Kechapi, Santol	Sandoricum koetjape (S. indi-cum)	24**; 22**
Kumquat	Fortunella margarita	**51**
Langsat: see Duku		
Lime	Citrus aurantifolia	37; **53**
Lychee	Litchi chinensis	31,32,48,49; **58**
Longan	Dimocarpus longan (Euphoria longana)	24,31,37,60; **57**
Loquat	Eriobotrya japonica	24,31; **48**
Macadamia	Macadamia integrifolia	32; **41**
Malay apple, Pomerac	Syzygium malaccense (Eugenia malaccensis)	24; **33**

Common name(s)	**Botanical name (Former name)**	Page; **nr** in Appendix
Mamey sapote	Pouteria sapota (Calocarpum sapota)	24**; 62**
Mandarin, Tangerine	Citrus reticulata (C. nobilis)	12,19,33,56,59,64; **54**
Mango	Mangifera indica	8,12,13,16,17,18,19,23,24, 28,31,32,34,37,38,48,49,50, 51,52,53,54,55,56,59,6,0,61, 65,66,69; **2**
Mangosteen	Garcinia mangostana	24,28,34,37,38; **19**
Marula	Sclerocarya birrea	**6**
Mombin (red), Spanish plum	Spondias purpurea (S. dul-cis)	28; **4**
Mombin (yellow), Hog plum	Spondias mombin (S. lutea)	28; **5**
Nashi, Pear (oriental)	Pyrus pyrifolia (P. serotina)	24,25,30,34,46,53; **45**
Nutmeg	*Myristica fragrans*	23,28,34
Oil palm	*Elaeis guineensis*	21
Papaya	Carica papaya	6,12,15,16,19,20,21,22,23, 34,36,37,55,56,58,65; **14**
Passionfruit	Passiflora	23,34,36,37,42,58,62
Passionfruit (purple)	Passiflora edulis f. flavicarpa	**39**
Passionfruit (yellow)	Passiflora edulis f. edulis	**40**
Peach	Prunus persica	30,45,53; **46**
Peach palm, Pejibaye	Bactris gasipaes (Guilielma speciosa)	**36**
Pear (oriental): see Nashi		
Pejibaye: see Peach palm		
Persimmon (black)	Diospyros digyna	24; **15**
Persimmon (oriental), Kaki	Diospyros kaki	24,57; **16**
Pineapple	Ananas comosus	6,12,13,14,15,19,21,22,34, 37,56,57; **13**
Pitanga, Surinam cherry	Eugenia uniflora	**31**
Plantain: see Banana		
Plum	Prunus salicina (P. triflora)	24,25,30,37,44,46,53; **47**
Pomegranate	Punica granatum	24,25,31; **42**
Pummelo	Citrus maxima	**56**
Rambutan	Nephelium lappaceum	12,23,24,28,29,34,49,52,55, 57,59; **59**
Rubber	*Hevea brasiliensis*	28,37
Salak	Salacca zalacca (S. edulis)	58; **37**

Common name(s)	**Botanical name (Former name)**	Page; **nr** in Appendix
Santol: see Kechapi		
Sapodilla: see Chiku	Manilkara zapota (Achras sapota)	
Sisal	*Agave sisalana*	21
Soursop	Annona muricata	28,34,36,37,55; **10**
Spanish plum: see Mombin		
Starapple: see Caimito		
Strawberry	Fragaria x ananassa	37; **49**
Sugarapple, Sweetsop	Annona squamosa	45,55; **9**
Surinam cherry: see Pitanga		
Sweet orange	Citrus sinensis	33,34; **55**
Tamarind	Tamarindus indica	24; **21**
Tangerine: see Mandarin		
Tea	*Camellia sinensis*	41,43
Wax jambu: see Java apple		
White sapote: see Casimiroa		